NASA CR-66510
(NSL 67-300)

ORBITING EXPERIMENT FOR STUDY OF EXTENDED WEIGHTLESSNESS

Volume IV

LABORATORY TEST MODEL

Prepared under Contract No. NAS1-6971 by
NORTHROP SYSTEMS LABORATORIES
Hawthorne, California
for
Langley Research Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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ABSTRACT

This document constitutes a portion of the final report under contract NAS 1-6971, Orbiting Experiment for study of Extended Weightlessness, for the Langley Research Center, National Aeronautics and Space Administration, Hampton, Virginia. The following 6 documents comprise the total report:

NASA CR-66507	Volume I	Summary
NASA CR-66508	Volume II	System Definition
NASA CR-66509	Volume III	Spacecraft Preliminary Design
NASA CR-66510	Volume IV	Laboratory Test Model
NASA CR-66511	Volume V	Program Plans
NASA CR-66512	Volume VI	Orbiting Primate Spacecraft Applications

This report summarizes the results of a definition study of a spacecraft system to support two primates in unattended, weightless, earth-orbital flight for extended periods of time. The experiment is planned as part of the Apollo Applications Program; the spacecraft launched as a LEM substitute on an AAP flight; the primates recovered by Astronaut EVA on a later flight and returned to earth in retrieval canisters within the Command Module. Intensive post-flight examination is planned to ascertain even subtle physiological changes in the primates due to their extended exposure to weightlessness. The study includes definition of mission profile and Apollo Applications Program interfaces, preliminary design of the spacecraft, and planning for subsequent phases of the program.

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ILLUSTRATIONS

TABLES

LIST OF ABBREVIATIONS

A	Analog
AAP	Apollo Applications Program
ACE	Automatic Checkout Equipment
ACM	Apollo Command Module
ACS	Attitude Control System
A/D	Analog to Digital
AFB	Air Force Base
AGC	Automatic Gain Control
Ag-Zn	Silver-Zinc
APC	Automatic Phase Control
APIC	Apollo Parts Information Center
AM	Airlock Module
ASME	American Society for Mechanical Engineers
ASPR	Armed Services Procurement Regulation
ATM	Apollo Telescope Mount
AVD	Avoidance Component
B	Biological
BCD	Binary Coded Decimal
BLO	Phase Lock Loop Bandwidth of Ground Receiver
BPM	Beats Per Minute
BW	Bandwidth
C	Control (Present)
C&C	Command and Control
CCW	Counter-Clockwise
C/D	Count Down

CDR	Critical Design Review
CEI	Contract End Item
CG	Center of Gravity
CIBA	CIBA Parmaceutical Company
C_L	Centerline
CM	Command Module
Cmds	Commands
C/O	Checkout
CO_2	Carbon Dioxide
CONFAC	Configuration Factor Computer Program
CRB	Configuration Review Board
CSM	Command Service Module
CW	Clockwise
D	Degradation
DAF	Data Acquisition Facilities
DB	Decibel
DCASR	Defense Contract Administrative Service Region Agent
DFO	Director of Flight Operations
DMU	Dual Maneuvering Unit
DOD	Department of Defense
DR	Discrepancy Report
DRD	Document Requirement Description
DRL	Data Requirements List
DRR	Document Request and Release
DSIF	Deep Space Instrumentation Facilities
E	Engineering
E	Event

ECG	Electrocardiogram
ECP	Engineering Change Proposal
ECS	Environmental Control System
ECU	Environmental Control Unit
EDS	Experiment Data System
EKG	Electrocardiogram
EO	Engineering Order
EMI	Electromagnetic Interference
ETR	Eastern Test Range
EVA	Extravehicular Activity
EXC	Exercise Component
FAB	Fabrication
FACI	First Article Configuration Inspection
FARADA	Failure Rate Data Program
FC-75	Minnesota Mining & Manufacturing (Product Designator)
FM	Frequency Modulated
FMEA	Failure Mode, Effect, and Analysis
FMECA	Failure Mode, Effect, and Criticality Analysis
FOV	Field-of-View
FSC	Flight Spacecraft
FTM	Functional Test Model
GAEC	Grumman Aircraft Engineering Corporation
G&C	Guidance and Control
GCPY	Gas Consumed Per Year
Gen.	Generator
GETS	Ground Equipment Test Set

GFE	Government Furnished Equipment
Gnd	Ground
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
h	Unit of Hysteresis
Hg	Mercury
Hz	Hertz
ICD	Interface Control Document
I.D.	Inside Diameter
IDD	Interface Definition Document
IDEP	Interservice Data Exchange Program
ILK	Interlock Task
I/O	Input/Output
IR	Infrared
IU	Instrument Unit
KC	Kilocycles
Kg	Kilogram
KSC	Kennedy Space Center
LEM	Lunar Excursion Module
LES	Launch Escape System
LiOH	Lithium Hydroxide
LM	Lunar Module
LMS	Lunar Mapping System
LMSS	Lunar Mapping and Survey System
LOS	Line-of-Sight
LRC	Langley Research Center

LSS	Life Support System
LTM	Laboratory Test Model
LUT	Launch Umbilical Tower
LV	Launch Vehicle
M	Mission
MAA	Maintenance Assembly Area
MAAS	Manufacturing Assembly and Acceptance Sheet
MC	Control Moment
MCC-H	Mission Control Center - Houston
MCP	Management Control Plan
MDA	Multiple Docking Adapter
MEI	Master End Item
MFOD	Manned Flight Operations Division
MHz	MegaHertz
MLF	Mobile Launch Facility
M&O	Mission and Operations
MOL	Manned Orbiting Laboratory
MRB	Materials Review Board
MS	Multiple Schedule
MSC	Manned Spacecraft Center
MSF	Manned Space Flight
MSFC	Marshall Space Flight Center
MSFN	Manned Space Flight Network
MSOB	Manned Spacecraft Operation Building
M/VM	Mass/Volume Measurement
M/V MD	Mass/Volume Measurement Device

N	Nuisance
NA	Not Applicable
NAA	North American Aviation, Inc.
NAMI	Naval Aerospace Medical Institute
NASCOM	NASA Communications Division
NASCOP	NASA Communications Operating Procedures
NRZC	Non-Return to Zero Change
NSL	Northrop Systems Laboratories
OCP	Operational Checkout Procedures
O.D.	Outside Diameter
OMSF	Office of Manned Spaceflight
OPS	Orbiting Primate Spacecraft
P	Performance (past)
PAM	Pulse Amplitude Modulation
PCM	Pulse Code Modulation
PCU	Pyrotechnic Control Unit
PDR	Preliminary Design Review
PERT	Program Evaluation Review Techniques
PI	Principal Investigation
PIA	Preinstallation Acceptance (test)
PLSS	Portable Life Support System
PM	Phase Modulation
PPM	Parts Per Million
PRINCE	Parts Reliability Information Center
PSC	Primate Spacecraft
PWR	Power
Q	Quick look

QA	Quality Assurance
QC	Quality Control
QM	Qualification Model
QTM	Qualification Test Model
R	Redundant feature
Rad	Irradiation dose unit of measurement
Rad.	Radius
RCS	Reaction Control System
RF	Radio Frequency
RH	Relative Humidity
RMS	Root Mean Square
RTG	Radioisotope Thermoelectric Generator
S	Saftey
SAA	Saturn Apollo Applications
S/AAP	Saturn Apollo Applications Program
S/C	Spacecraft
SCD	Specification Control Drawing
SCN	Specification Change Notice
Seq	Sequence
SGL	Space Ground Link
SIB	Saturn IB
SLA	Spacecraft LEM Adapter
SM	Service Module
SNR	Signal to Noise Ratio
SPS	Service Propulsion System
SRO	Superintendent of Range Operations
STADAN	Space Tracking and Data Acquisition Network

STM	Structural Test Model
TCM	Thermal Control Model
TCS	Thermal Control Subsystem
TE	Time Estimation
TIG	Tungsten Inert Gas
TIM	Timing Task
TLM	Telemeter
TM	Thermal Model
TTM	Thermal Test Model
TWT	Traveling Wave Tube
UCLA	University of California at Los Angeles
USC	University of Southern California
UV	Ultraviolet
VAB	Vertical Assembly Building
VCO	Voltage Controlled Oscillator
VIG	Vigilance Task
VOM	Volt-Ohmmeter
WMS	Waste Management System
WMU	Waste Management Unit
WTR	Western Test Range

INTRODUCTION

The Orbiting Experiment for Study of Extended Weightlessness will study the effects of weightlessness on two unattended primates, Macaca mulatta, while in earth orbit for one year. This will be accomplished using an Orbiting Primate Spacecraft specifically designed to provide life support for two unrestrained animals. The animals will be instrumented to provide physiological and behavioral data. After one year in orbit the animals will be returned to earth in an Apollo Command Module for pathological studies. The spacecraft will also be instrumented to provide long term life support experience.

The purpose of the Laboratory Test Model is to prove under laboratory conditions the design adequacy of the life support equipment proposed for use in the Orbiting Primate Spacecraft. The Laboratory Test Model will also provide accurate scaling factor data for oxygen, food and water usage and will provide data concerning contamination control and waste management within a closed environmental control system. This data will be used in the final spacecraft designs. In addition, the Laboratory Test Model will provide a realistic training and behavioral environment for two laboratory animals. Data gathered from the animals will be used to provide an improved behavioral regimen in the space experiment and will provide baseline control data for the behavior of these animals in a closed environment such as that proposed for the Orbiting Primate Spacecraft.

The Laboratory Test Model contains all of the equipment that normally interfaces with the animal during actual space flight and contains all of the life support equipment required to maintain the animals in an uninterrupted closed environment for one year. In addition, the necessary instrumentation and recording equipment needed to provide data regarding the performance of the animals and the equipment under test is provided.

The model is designed to be operated in an air conditioned laboratory to be designated by the NASA. The final design and construction of the model will be completed in time to permit results of the closed environment test to be used in the final designs of the spacecraft and in experiment planning.

The following sections of this Volume describe in detail the performance requirements for the Laboratory Test Model, the proposed design, and constrution for the Laboratory Test Model and the operational test procedures.

LABORATORY TEST MODEL REQUIREMENTS

Functionally the Laboratory Test Model (LTM) and the Orbiting Primate Spacecraft itself are identical. However, a major operational difference exists between the two in that the Laboratory Test Model is constrained to operate in a one g environment in a ground based laboratory facility.

To meet the basic test objectives listed in the Introduction, certain engineering and experimental requirements must be met as specified in the following subsections.

Engineering Requirements

Engineering requirements are those necessary to assure that the test hardware is properly installed and functions adequately throughout the test period. The basic engineering requirement dictates that the Laboratory Test Model be designed to operate in an air conditioned laboratory for unattended periods of up to 24 hours. Second, the Laboratory Test Model must be capable of operating at least one year using equipment designed to accommodate supplies of expendables and consumables sufficient for a one year operating lifetime excluding nitrogen and oxygen breathing gases. Third, the Laboratory Test Model must be designed to allow replacement of key components while the test is in operation without disturbing the animal atmosphere beyond the normal limits of operation.

Items that will be designed to be replaced are:

(1) Food pellet dust filter

(2) Main ECS blowers

(3) Secondary ECS blowers

(4) Gas analyzer

(5) Television camera

Finally, engineering instrumentation must be provided in each of the subsystem areas to the extent necessary to evaluate life support equipment performance during the test period. These data will be monitored and recorded on equipment normally found in a well-equipped electronics laboratory.

Experimental Requirements

Experimental requirements are those necessary to assure a quantity and quality of data that is adequate to meet the test objectives. The basic experimental requirement dictates that the Laboratory Test Model equipment exposed to both the animals must be identical to that proposed for the Orbiting Primate Spacecraft throughout the uninterrupted one year operating period. The Laboratory Test Model must provide sound isolation for both animals so that neither is aware of normal laboratory noise. Further, measurements must be made of life support environment factors including animal metabolic consumptions of oxygen, water, food and the contamination outputs of the animal and his waste products. Detection of possible contamination constituents introduced into the life support system by equipment must be provided. Sampling of the animal's environmental atmosphere must be provided along with a system to observe and photograph the animals without their awareness. Finally, GFE behavioral task control and monitoring equipment must be accommodated.

Complete and detailed Laboratory Test Model requirements are listed in NSL 67-323, MEI Detail Specification Laboratory Test Model For Orbiting Experiment For Study of Extended Weightlessness Project.

LABORATORY TEST MODEL DESCRIPTION

The Laboratory Test Model is a functional and in some areas a physical representation of the spacecraft and its subsystems. Its design is predicated upon demonstration of performance of certain critical spacecraft elements such as environmental control, waste management, feeder, waterer, life cell, behavioral panel, which directly interface with the primates. These are the items which closely approximate final spacecraft equipment configurations. Other required support is provided by equipments functionally equivalent to the spacecraft counterparts where the particular functions are necessary to the Laboratory Test. Where it is not feasible or will not contribute significantly to the information obtainable from the testing to incorporate certain spacecraft subsystem elements in the Laboratory Test Model, these are omitted. Examples of equipment in this category are: Attitude Control, Structure and Mechanical Subsystems, water storage and solar array.

Laboratory Test Model Configuration

The overall configuration of the Laboratory Test Model is shown in figure 1 while the Master End Item Configuration Tree is shown in figure 2. Figure 3 shows the overall relationship of the Laboratory Test Model and the supporting laboratory facilities. As reflected in figure 1, the entire container constitutes a pressure vessel in which the life cells are installed. A removable covering and seal at one end permits access to the interior while special sealed covers over each feeder permit access to these units. A simulation of the recovery capsule is also included and is shown at the top of the structure. The general configuration philosophy which was followed was to install that equipment externally where possible which it was felt might require maintenance during the testing period. This approach was used as a guide but did not prevail where the validity of the test results might be compromised. Thus principal items of equipments such as the contaminant and circulating fans, feeder pellet dust filter, gas analyzer, television cameras are externally located while units such as the heat exchanger, condenser, catalytic burner, regenerator, pressure relief valve, purge valve, dump valve and associated ducting are internally installed. Viewing of the interior of the structure from the outside is possible through sealed view ports while the televising of the interior of the life cell is accomplished by means of the externally installed television camera. A light proof shielding is provided around the television camera to prevent stray light from entering the life cell.

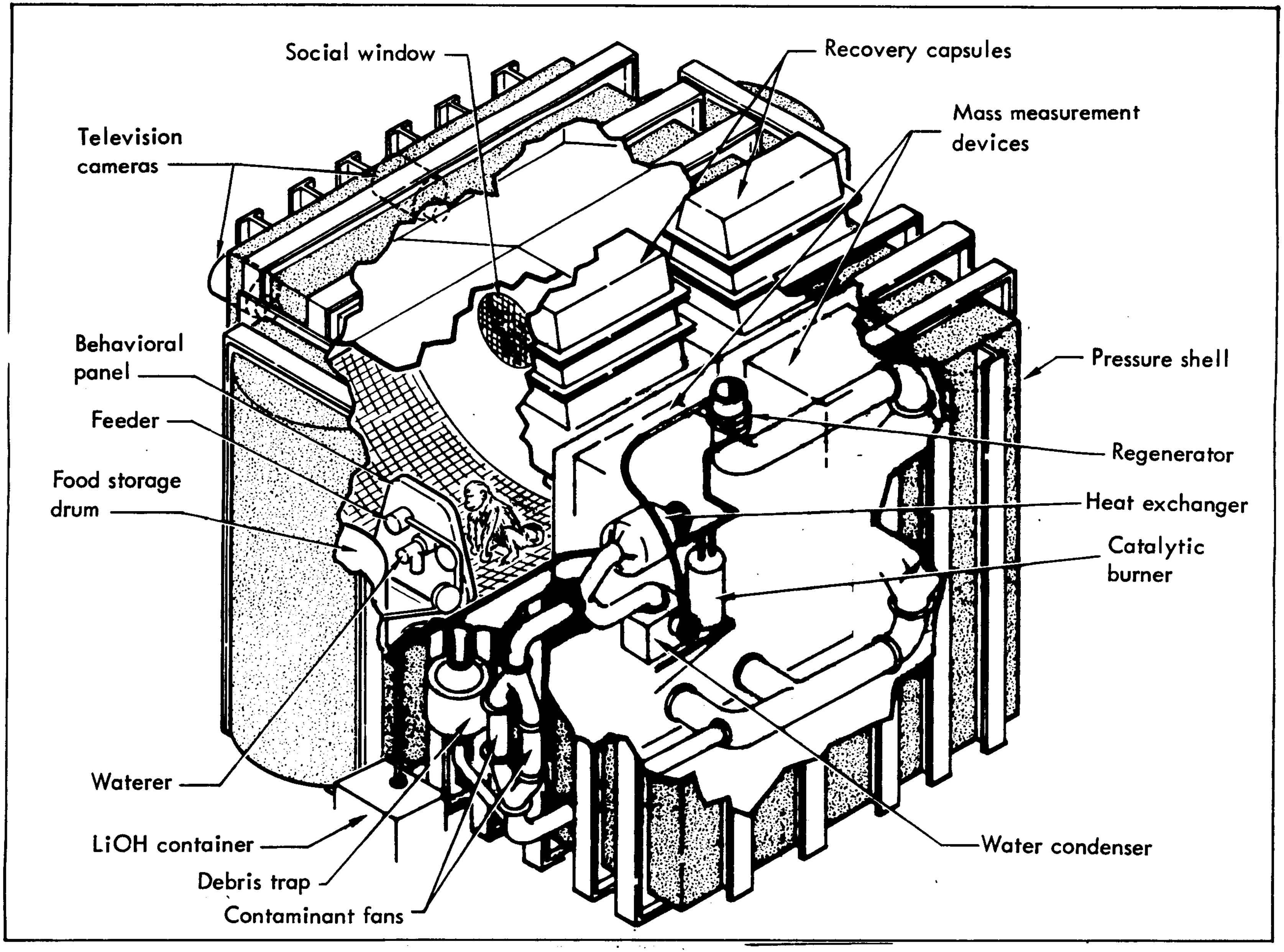


Figure 1. - Laboratory test model configuration

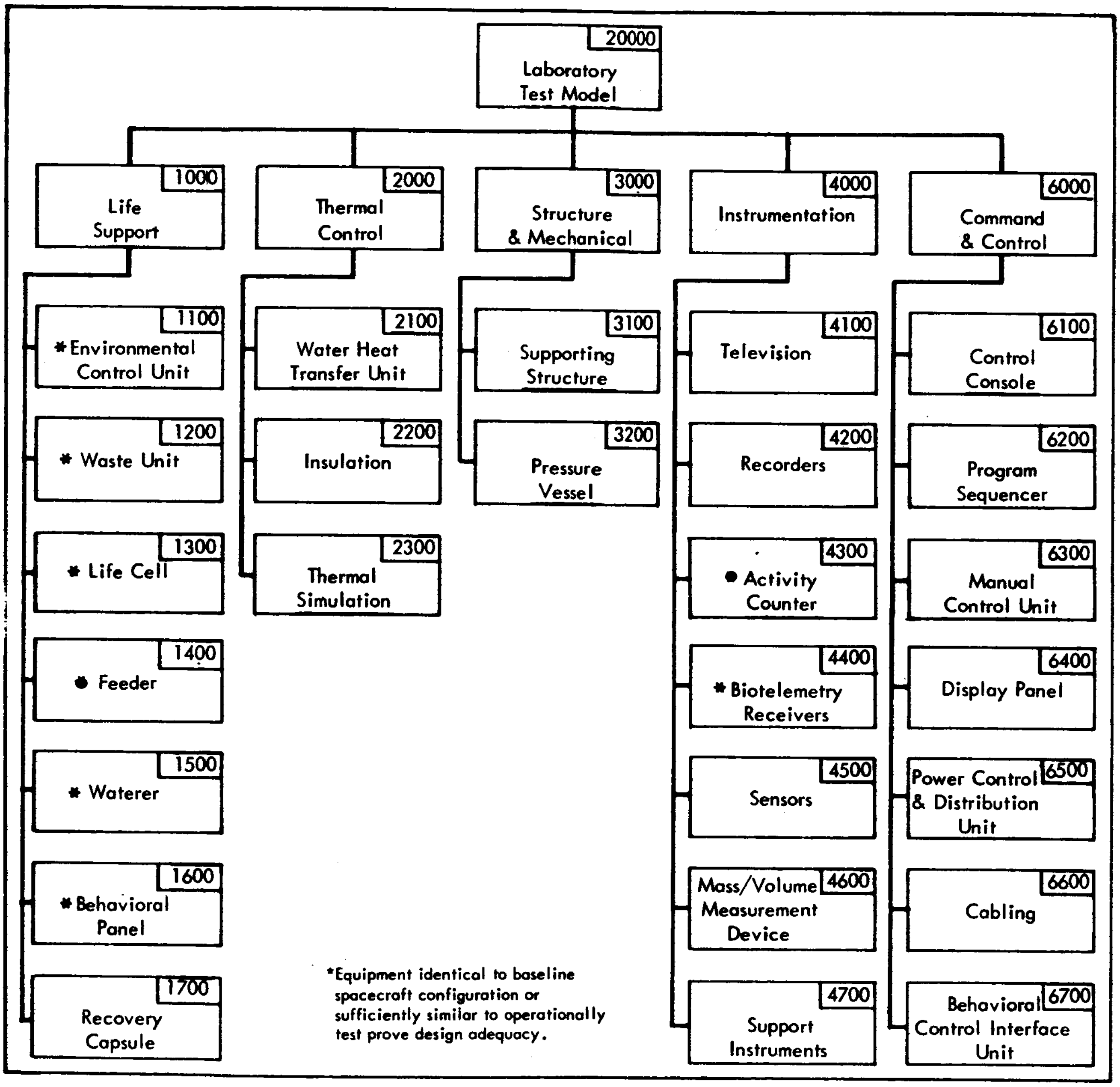


Figure 2.– Laboratory test model master end item configuration tree

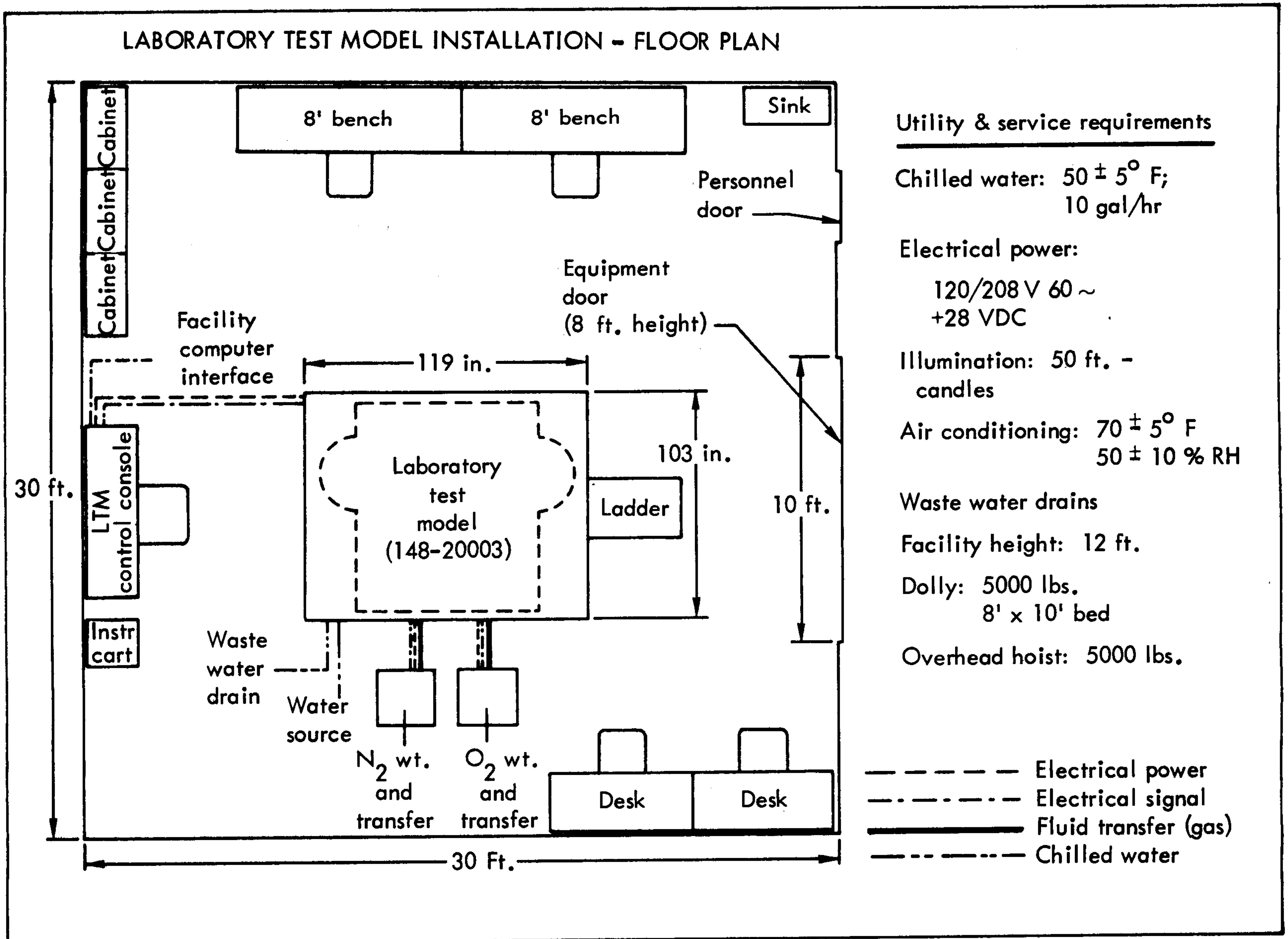


Figure 3.—Laboratory test model installation

Laboratory Test Model Subsystem Summary

The subsystems which form the Laboratory Test Model are designated as follows:

(1) Life support

(2) Thermal control

(3) Structure and mechanical

(4) Instrumentation

(5) Command and control

A broad view and summary of the various subsystem functions and mechanizations is presented here while a detailed discussion is contained in a later section. The overall interrelationships between the various subsystems are reflected in figure 4.

Life support. - The Life Support Subsystem provides the vital functions required by the primate. These are summarized in table 1.

Thermal control subsystem. - The Thermal Control Subsystem provides the heat sink for the thermal outputs of the environmental control subsystem and for simulation of spacecraft thermal loads for enhancement of testing validity. These functions are summarized in table 2.

Structure and mechanical subsystem. - The Structure and Mechanical Subsytem provides the external support for the entire Test Model in the laboratory as well as the basic structure of the model itself. It is summarized in table 3.

Instrumentation subsystem. - The Instrumentation Subsystem provides for the monitoring of the primates and the subsystems forming the Laboratory Test Model. The functions are summarized in table 4.

Command and control subsystem. - The Command and Control Subsystem performs a diversity of functions involving equipment control, sequencing and switching, displays, power and signal distribution. Table 5 summarizes these functions.

Interfaces. - The general interfaces between the Laboratory Test Model and the laboratory facilities are shown in figure 5 while figure 6 shows the specific interfaces between the life cell and supporting functions. Table 6 presents an interface matrix between the subsystems identified in figure 2 and also reflects the primate interactions.

Weight summary. - The estimated weight of the Laboratory Test Model excluding storables such as oxygen, nitrogen and water is summarized in table 7. As noted, the weight includes the model structure, all attachments which form part of the shipped assembly and the contents of the pressure vessel. The support table is an exception in that it does not form an integral part of the model assembly.

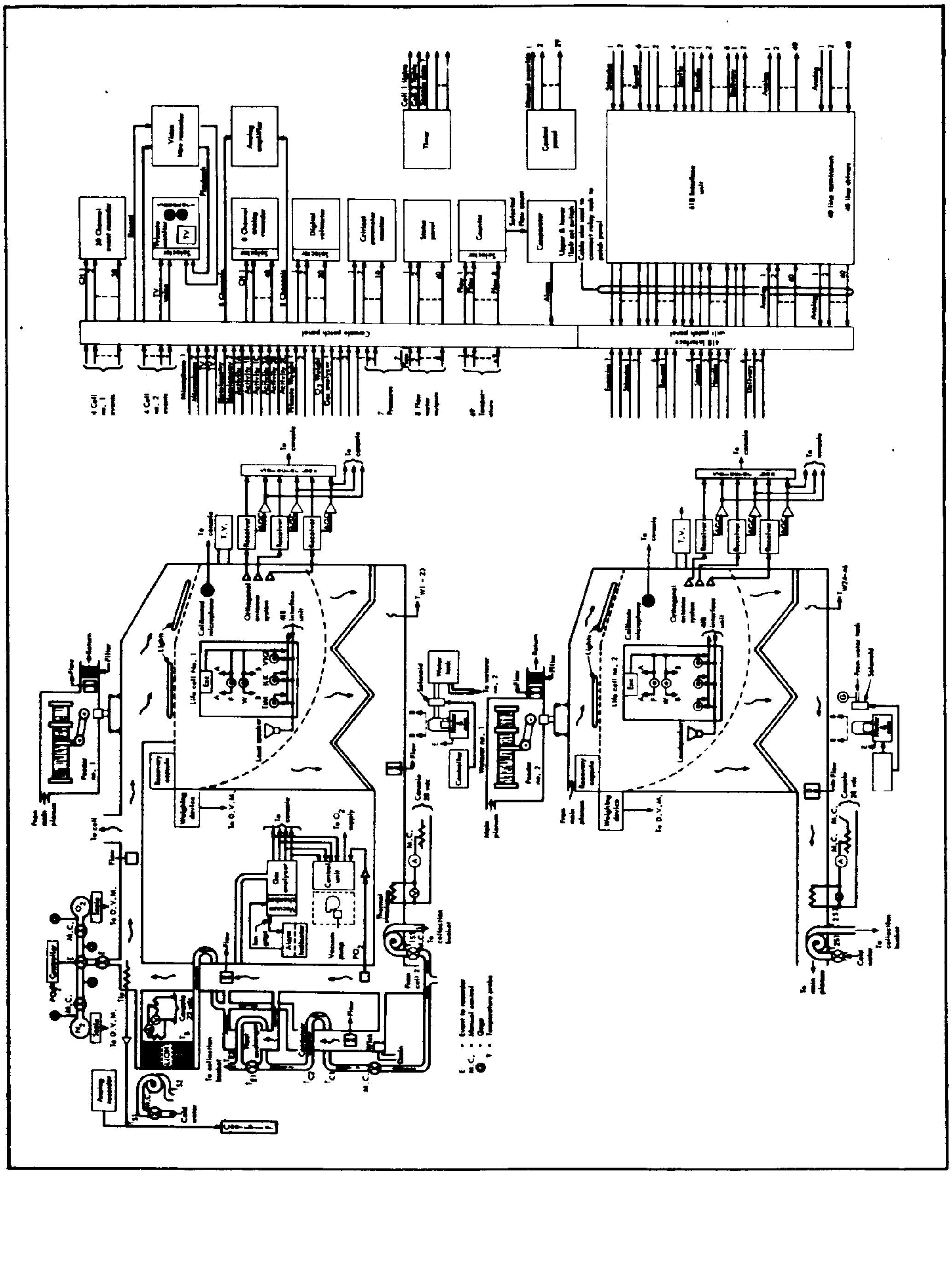


Figure 4. Laboratory test block diagram

TABLE 1. - LIFE SUPPORT SUBSYSTEMS SUMMARY

Function	Mechanization	Remarks
Environmental control	High pressure storage - oxygen, nitrogen	External tanks used
	Partial pressure oxygen and atmosphere composition monitored - use same gas analyzers as spacecraft; gas flow controlled as function of oxygen partial pressure and atmosphere total pressure.	Manual override of oxygen regulations and flow provided.
	Redundant circulation fans used.	Fans externally located, similar in design to spacecraft equipment.
	Redundant fans used as part of humidity, temperature and carbon dioxide controls in conjunction with heat exchanger/condensor loop.	
	Condensing heat exchanger for humidity control, sensible cooling.	Similar to spacecraft equipment.
	Heat rejection to heat exchanger and fluid transport loop of thermal control subsystem.	
	Lithium hydroxide used for carbon dioxide removal.	Lithium hydroxide container externally located.
	Absorbent beds and catalytic burner provide primary control of trace contaminants.	Similar to spacecraft equipment.
	Ultraviolet used for control of air borne bacteria.	Similar to spacecraft equipment.
Waste management	Graded porosity filter used to collect and store waste in 1 g field; waste is air dried within pressure shell.	Similar to spacecraft equipment except provisions made for period sampling.
Living area	Use spacecraft life cell.	
Task performance	Spacecraft Behavioral Panel used. Food and water supplied through panel mouthpieces.	Panel serves as interface between primate and feeder/waterer.
Feeding	Spacecraft feeder and food disposing used.	Food pellets composition and packaging same as spacecraft.
Watering	Water disposing same as spacecraft; water storage by means of external tanks at 25 psig.	Single tank used for both primates.
Recovery	Same physical characteristics as spacecraft unit except no self contained environmental control.	

TABLE 2. - THERMAL CONTROL SUBSYSTEM SUMMARY

Function	Mechanization	Remarks
Provide heat sink for Life Support	Active transport loops using water coolant from facility	Simulates spacecraft active thermal control interface
	Interfaces with Life Support ECS heat exchanger and condenser	
	Constant temperature source of 50 ± 5°F at 10 gal per hr	Constant temperature source provided by facility
		Water is dumped after use
Provide thermal isolation	Use Min-K thermal insulation	Simulates insulation used on spacecraft
	Thermal insulating material used at test model and mountings stand interface	
Simulate thermal inputs and losses	Strip heaters interfacing with Life Support ECS	Strip heaters simulate electronic, earth, and sun heat inputs to spacecraft
	Active water loop interfacing with Life Support ECS	Chilled water simulates unintentional heat losses of spacecraft to space

TABLE 3. - STRUCTURE AND MECHANICAL SUBSYSTEM SUMMARY

Function	Mechanization	Remarks
Test model support	Platform of 5" steel H-beams; welded construction	Attaches and supports Laboratory Test Model and associated external support equipment
Pressure vessal structure	111" x 84" x 111" overall dimensions not including 4" of thermal insulation	Withstands positive pressure of 4.5 ± 0.5 psig
	1/4" aluminum sheet, stiffened with aluminum T sections	Insulation to be installed over external T section stiffeners
	Removable end for accessibility to pressure vessal interior	
	Removable cover for feeder to provide access	

TABLE 4. - INSTRUMENTATION SUBSYSTEM SUMMARY

Function	Mechanization	Remarks
Visual monitoring	Modified commercial type (Sony) television closed loop monitor to be used	Camera is externally mounted
	Straylight shielding for view port provided	Frame and field of view characteristics same as spacecraft equipment
	10 frames/sec at 250 lines/frame	
	Camera removable to permit direct viewing	
	80° wide angle and 10° narrow angle lens	
Bioinstrumentation and activity monitor	Use same configuration as spacecraft except commerical receivers	Data is recorded directly on external recorder
Subsystem monitoring	Utilize standard transducers	Load cells are Dillon types with digital voltmeter read outs
	Use flow meters to measure fluid flow	
	Partial pressure measurements by mass spectrometer (Perkin Elmer)	
	Load cells used to weigh oxygen and nitrogen supplies	
Mass measurement	Use load cell with external, remote readout	
Voice monitor	Use calibrated microphones in each life cell	Manual selection with output to loudspeaker, oscilloscope or recorder
	Use strip chart recorders for gas analyzer outputs	
	Event recording by means of 30 channel Brush recorder	
	Thermocouple outputs recorded by Honeywell recorder	
	Video and voice recorded on Sony EV-200 type video recorder	

TABLE 5. - COMMAND AND CONTROL SUBSYSTEM SUMMARY

Function	Mechanization	Remarks
Control integration	Provide central control console with displays.	
	Use commercial type patch panel for interconnections, etc.	
Sequencing and switching	Timed sequencing by commercial type timer control.	
	Remote switching by means of relays.	
	Direct manual switching used where feasible.	
	Programmed operations initiated Laboratory 418 Computer	Interface unit required between computer and control console patch panel.
Display	Use audio, visual and oscilloscope displays	Lights used for position limits and activity occurrences.
	Control display panel provided	Motors used for voltage, currents and some position indications.
		Audio and visual alarms for unsafe conditions.
Power control and distribution	Laborabory 115V/208V, 60 Hz and + 28 vdc used.	Emergency standby power with automatic transfer required
	Manual circuit breakers used for circuit protection	
	Selective cabling and wire routing used to minimize EMI	

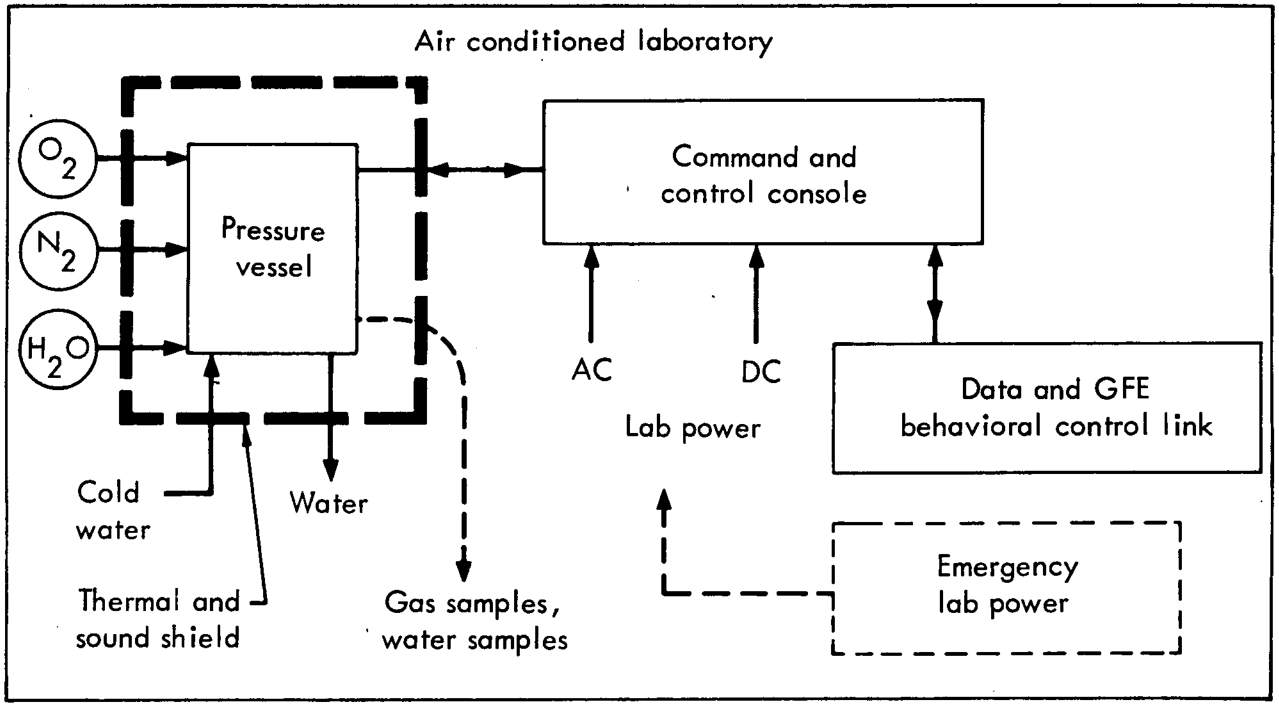


Figure 5.– System interface definition

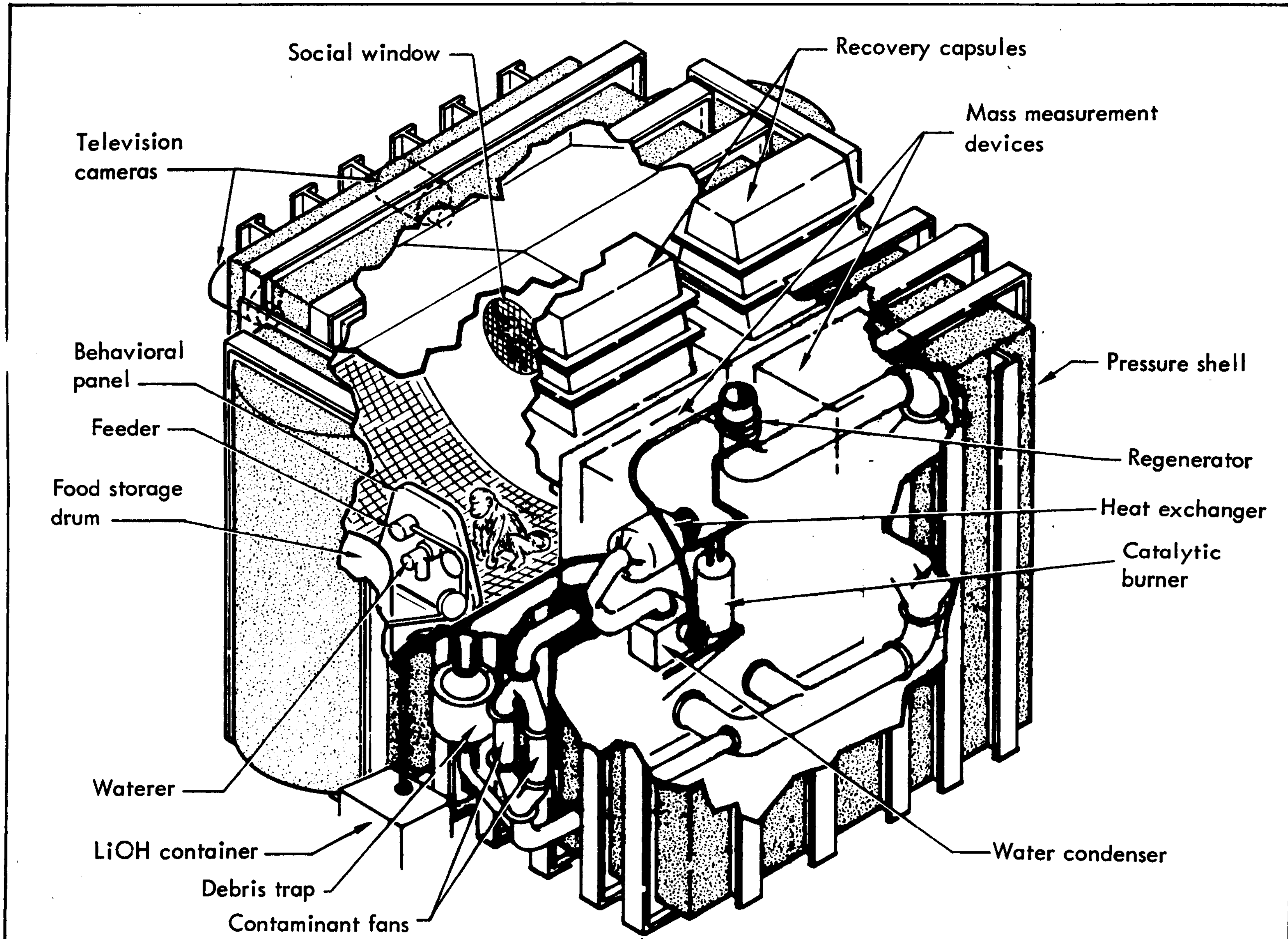


Figure 6. - Primate/life cell interface

TABLE 6. - SUBSYSTEMS INTERFACE MATRIX

Performed for / Performed by	1. Life support	2. Thermal control	3. Structure and mechanical	4. Instrumentation	5. Command and control	6. Primate
1. Life support						Provides food, water, shelter, atmosphere, temperature control and programmed tasks
2. Thermal control	Provides heat sink using heat exchanger and active loop with laboratory facility cold water used as coolant		Provides heating and cooling to stimulate heating and cooling loads	Provides passive temperatue control	Provides passive temperature control	
3. Structure and mechanical	Provides sealable pressure shell capable of withstanding 5.0 psig positive pressure, structural support and accessibility	Provides structural support and heat sinks		Provides structural support and accessibility	Provides structural support and accessibility	
4. Instrumentation	Provides for monitoring of performance parameters and behavioral panel stimulus signals	Provides for monitoring of performance parameters	Provides for monitoring of performance parameters		Provides for monitoring of performance parameters	Provides receivers, multiplexer for ECG, TV monitoring, lighting, and voice monitoring
5. Command and control	Provides programmed and real time commands, electric power and switching facilities, and behavioral control interface facility	Provides programmed and real time commands and electric power and switch facilities	Provides power and switching facilities to mechanical actuating devices	Provides programmed and real time commands, and power and switching facilities		
6. Primate	Consumes oxygen, food, and water, activates behavioral panel and provides input to waste unit	Provides heat load		Provides support for implanted sensors		

TABLE 7. - LABORATORY TEST MODEL
WEIGHT SUMMARY

		Lbs.
Pressure shell		1500
Support table		800
Recovery capsules (2)		70
ECU and WMU (2)		545
Waterer (2)		20
Feeder (2)		340
Life cells and mechanisms		350
Thermal control and insulation		440
	Total	4065 lbs.

LABORATORY TEST MODEL SUBSYSTEM

The subsystems described in this section represent the mechanizations deemed necessary functions to either duplicate spacecraft equipment or to simulate spacecraft equipment. In all cases where a direct interface with the primate was involved, the decision was made to duplicate the spacecraft equipment. This was based on the fundamental guideline that this type of equipment should be tested and evaluated in a condition as close to the spacecraft configuration as possible. Where only a particular support function was required and no direct primate interface was involved, then a simulation of the spacecraft equipment function was deemed adequate. Where functions falling into neither of these categories were involved, such as laboratory instrumentation recorders, etc., then ordinary design judgement was employed considering cost and availability of standard equipment.

Life Support

The primary requirement of Life Support Subsystem is to provide the primates with environmental support which will permit unrestrained and monitored activity over a one year period. In addition, Life Support must provide an environment which is compatible with the primate to ensure a safe and uninfluenced space simulated experiment. To accomplish these goals, the Life Support Subsystem is divided into six elements - life cell, feeder, waterer, behavioral panel, environmental control and waste menagement, and recovery capsule. Figure 7 schematically illustrates the functional relationships of these subsystems. Subsequent sections will briefly describe individually these subsystems. Differences between the Laboratory Test Model and spacecraft subsystem will be highlighted.

Life cell. - The life cell is the central element of the Life Support Subsystem serving as an enclosure and living area for the primate. It is identical to the spacecraft life cell.

Life cell requirements: The Laboratory Test Model life cell requirement is to simulate the spacecraft life cell. This is accomplished by satisfying the following requirements:

(1) Physically the life cell should be 36 inches high, 30 inches wide and 40 inches long and the volume is 25 cubic feet.

(2) The ceiling of the life cell should be designed so as to cause minimum interfernce of television viewing, as well as to inhibit the monkey from grasping the ceiling or orienting toward the ceiling. The floor is required to provide foot-holds for the monkey and to present a minimum obstacle to passage of wastes. The cage is to contain no removable components or fasteners accessible from within. The interior must have a minimum of projections or obstacles which might collect wastes or impede their removal.

(3) Materials within the life cell should be capable of resisting scratching or chewing by the monkey and chemical attack by fresh or decomposing food, feces, or urine.

(4) The life cell should be illuminated at an intensity of 25 foot-candles for 14 hours per day. The light source should provide a spectrum approximating that of sunlight. During the ten-hour dark period, light intensity should be in the range of 0.01 to 0.10 foot-candle.

(5) Cages should provide for social interaction between monkeys which allows only finger and toe touching.

(6) Exercise is desirable to keep the monkey in good physiological condition. The posibility of providing exercise through a variable spring tension or a similar mechanical approach should be considered.

Life cell description and performance: The Laboratory Test Model contains two adjacent life cells connected by a social window in their common (inside) wall. The volume of a life cell is 25 cubic feet. The life cell is a truncated semi-cylinder. The radius is 36 inches with a depth of 30 inches as shown in figure 8. The cage walls and ceiling are smooth matt finish stainless steel panels with rounded edges and fitted corners to minimize the collection of

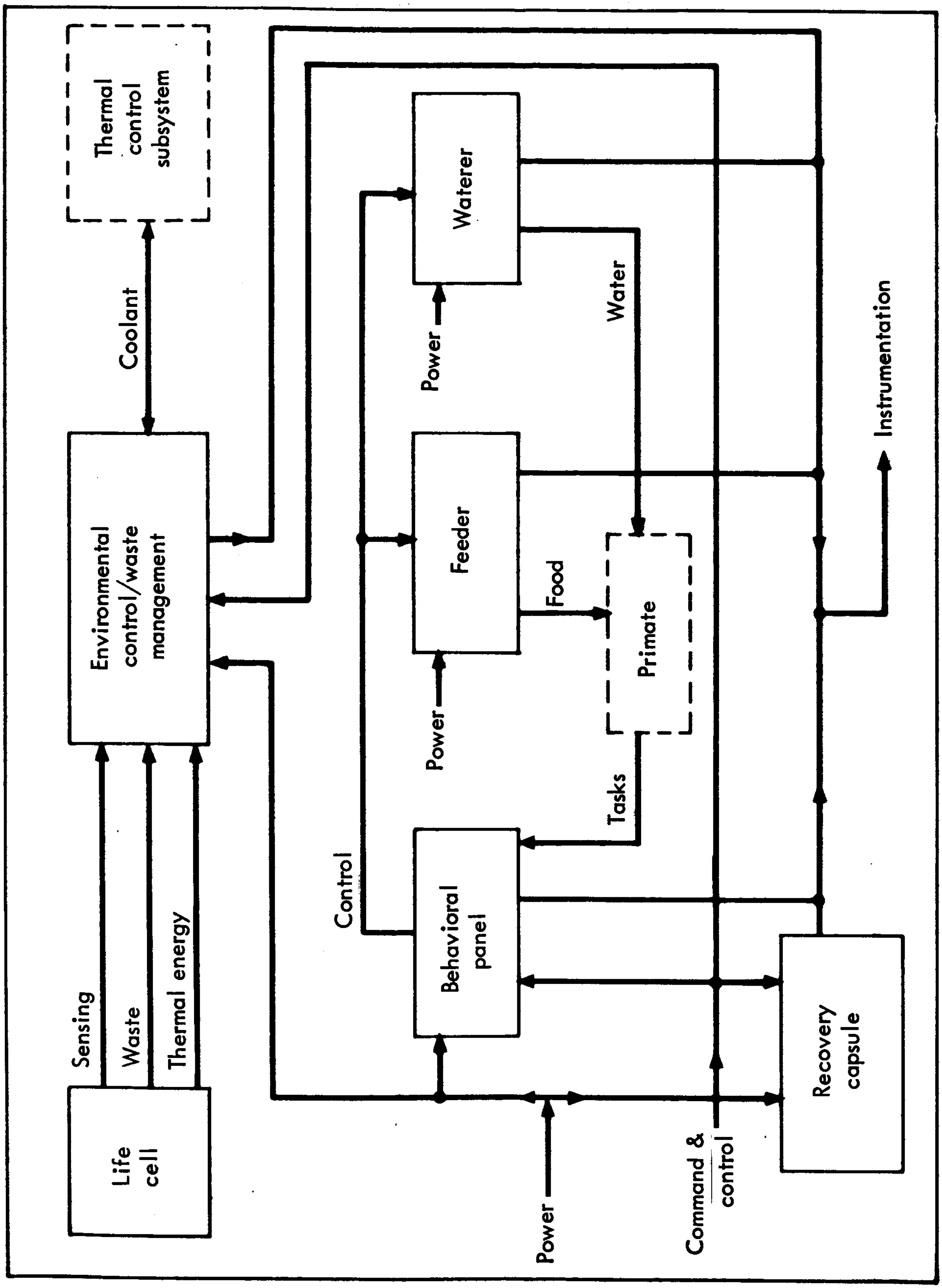


Figure 7.-Life support subsystem block diagram

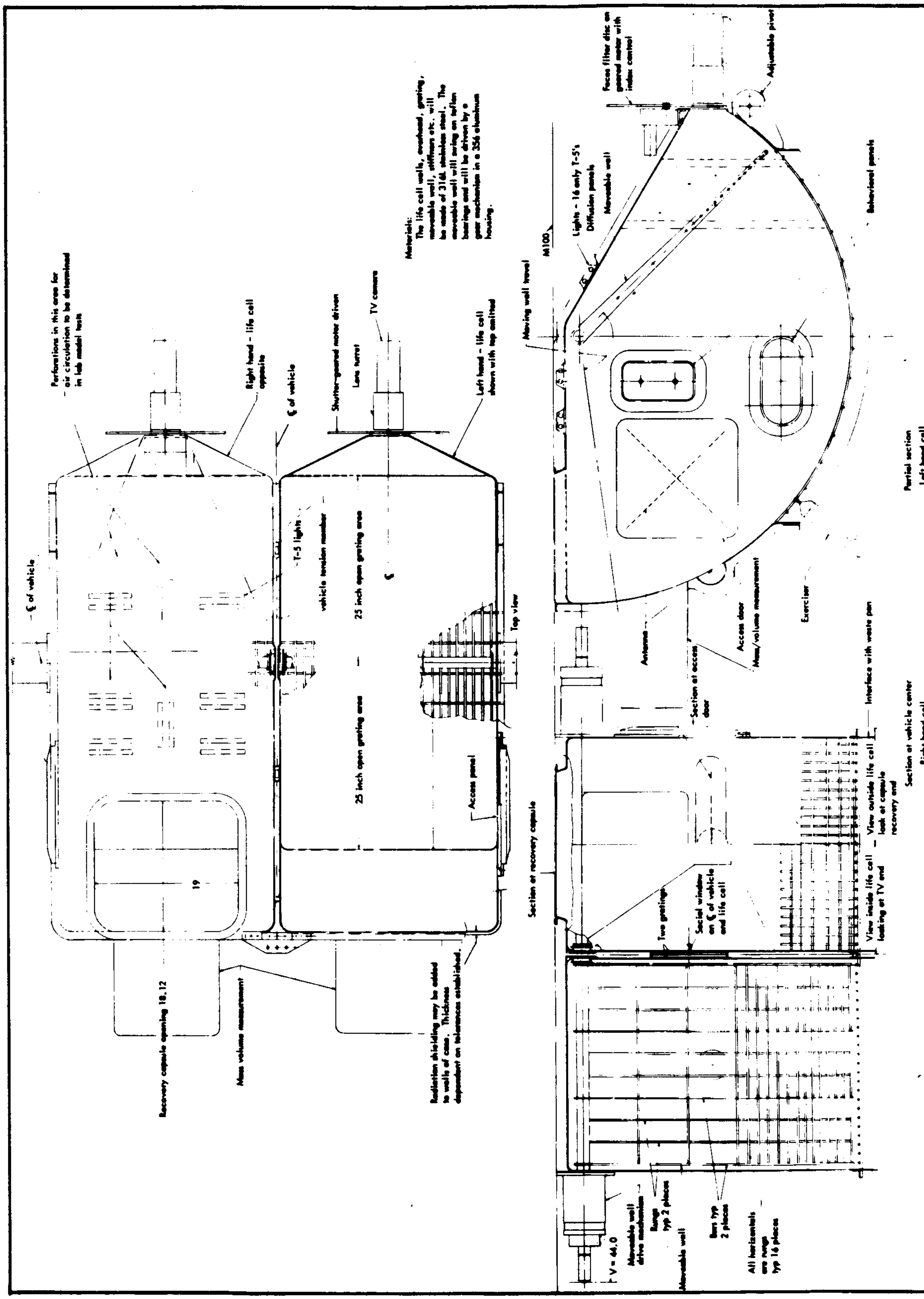


Figure 8.-Life cell

debris and the possibility of injury to the animal. The floor grill, moving wall, and social opening mechanism, are constructed of stainless steel tubes welded together at each intersection.

A one-inch clearance between the two cages isolates the two walls to reduce noise transmission and provide space for wall reinforcements, a pressure shell tie menber and cabling runs. This one-inch cage spacing also serves to separate the social opening screens. The selection of one-half inch square grill openings enables the animals to touch fingers or toes but they cannot bite each other through this social opening.

The television camera is located outside the Laboratory Test Model pressure shell and will view the cage through a glass plate. The television camera and optical window is shielded thoroughly from ambient light to prevent reflections into the television and to prevent the primate from seeing into the laboratory.

Life cell preliminary equipment list: A list of major equipment items, other than structural are shown in table 8. The equipment evaluated is developed and available.

TABLE 8. - LIFE CELL PRELIMINARY EQUIPMENT LIST

Item No.	Description	Suggested manufacturer	Part No.	Quantity per LTM
1	Geared motor	Globe Industries, Inc.	102A190-10	2
2	Geared motor	Globe Industries, Inc.	102A165-10	2
3	Industrial gear reducer	Harmonic Drive Div., United Shoe Machine Corp.	HDUC 40-120-1-GP	2

Feeder. - Basic animal nutritional requirements are furnished from a storage and dispensing device, as a reward for activities performed, or ad libitum. The feeders are identical to the ones used in the spacecraft.

Feeder requirements: A total of 54,750 one-gram pellets weighing 120 pounds for each animal must be loaded in a sterilized condition and kept sterile to the point of delivery. The animal food will be of a composition tested for laboratory maintenance of Rhesus colonies, such as CIBA Whole Diet Nutrient Pellets. On demand and per program, the monkey will be fed 150 pellets per day. The pellets must be enclosed at all times to prevent contaminiation. The delivery rate is on an average of one pellet per two and one-half minutes. Upon illumination of the stimulus light, the monkey will place his mouth over the mouthpiece and in about one-half second will receive a pellet. Reliability and freedom from contamination are the most important considerations. The primary requirements of the feeder are summarized as follows:

(1) Shall operate in a one atmosphere and under 1 g conditions.

(2) Shall dispense pellets directly into the animal's mouth in a manner acceptable to the animal.

(3) Shall not be susceptible to jamming through presence of wet or hardened feces or food in delivery nozzle.

(4) Shall prevent contamination of food from sources, such as moisture, feces, urine, or wet food in or on the delivery nozzle.

(5) Shall signal delivery of a pellet to an accuracy of 0.01 second.

Feeder description and performance: The design and construction of the feeder is shown in figure 9. The feeder utilizes 1 gram spherical food pellets encased in a regular track zipper tubing. Each feeder is loaded with 54,750, 1-gram pellets.

The food tube is spherical wound on a storage drum. This drum is restrained by a dragging brake. The food tube is removed tangentially from the food drum through a traveling lead block that articulates as layers are removed from the drum. The tube is unzippered at the food mandrel and the pellets are deposited in the mandrel where they are fed to a star wheel with four holes that are accurately positioned by a geneva mechanism.

A ram normally seals the delivery mouthpiece. To deliver a pellet, the ram retracts, the star wheel rotates a pellet into position and the ram reseats, thereby delivering a pellet to the primate. The empty food tube is wound flat upon a takeup reel. The prime mover of the food tube is the capstan located between the mandrel and the takeup reel.

A switch requires that the primate place its mouth over the delivery mouthpiece before it can receive a pellet.

Feeder preliminary equipment list: Table 9 represents a listing of mojor equipment items required to mechanize the preliminary design of the feeder. Most of the components as noted are already developed and readily available.

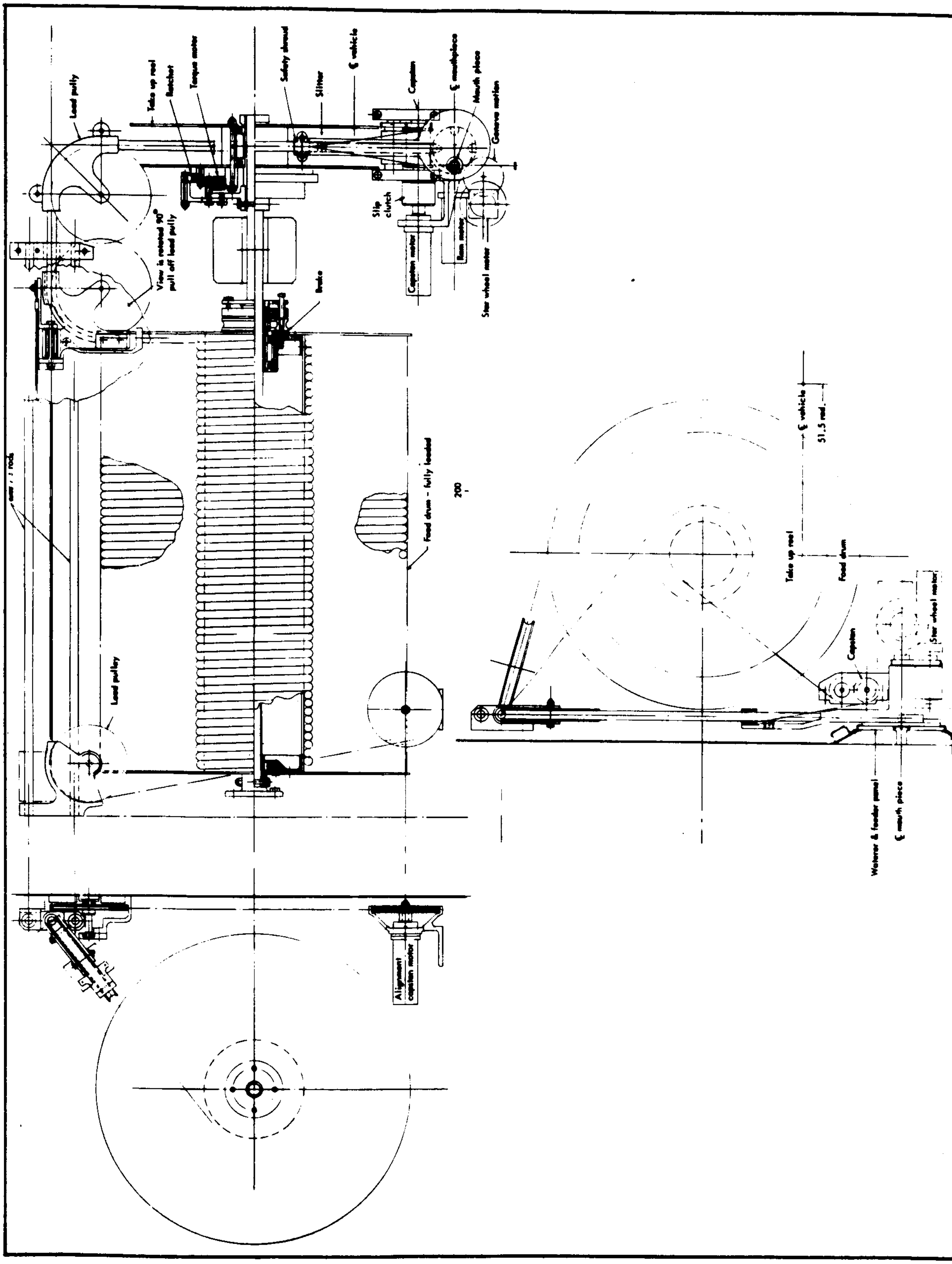


Figure 9.-Feeder

TABLE 9. - FEEDER PRELIMINARY EQUIPMENT LIST

Item no.	Description	Suggested manufacturer	Part no.	Quantity per LTM
1	Planetary gear motor	Globe Industries	102A190-9	4
2	Planetary gear motor	Globe Industries	102A193-11	4
3	Torque motor	Inland Motor Company	T4412	2
4	Zipper tubing	Zipper Tubing Company	Zt-0500	2-2200 ft./roll
5	Cam roll	McGill Company	CF-5/8	2
6	Spur gear	Boston Gear Company	NA 25B	8
7	Spur gear	Boston Gear Company	30B	4
8	External tangent drive	Geneva Motions Corporation	New	2
9	Linear ball bearing	Thompson Industries	A-81420	4
10	Ratchet ring gear	Boston Gear	NB-120	2

Waterer. - The waterer is extremely important to the success of the mission. Engineering data shall be gathered for assessment of the operation of the waterer, both for recognition of incipient failure and for evaluation of the system performance during the satisfactory one year operation.

In order to prevent contamination of the waterer, the waterer should prevent back contamination by desolved material, particulates, or microorganisms through the delivery nozzle. The water itself will be potable tap water. Mineral content will be limited to prevent corrosion or scaling and the water will be filtered-sterilized as it is placed in the storage tank. The potable tap water is being used because the animal normally requires the minerals contained in the water.

Waterer requirements: The waterer shall simulate the spacecraft design and appearance to the animal. It shall dispense measured amounts of water to the animal upon successful completion of a behavioral task by the animal.

The requirements affecting the waterer are as follows:

(1) The waterer shall deliver 2 cc aliquots to the animal at the rate of 1 cc/second for an average of 208 aliquots per day for one year without failure.

(2) A switch shall operate when the animal's mouth is on the mouthpiece, which size shall be compatible with the animal.

(3) The stored water shall not support or encourage growths of fungi or bacteria.

(4) The stored water shall remain uncontaminated.

(5) The water shall be delivered to the animal at life cell temperatures within ± 5 degrees F.

(6) The waterer shall operate in 1 g field environment.

(7) The waterer shall prevent buildup of contaminating solutes due to corrosion or leaching of component materials.

(8) The waterer shall provide a signal signifying delivery of an aliquot.

(9) The waterer shall signal time of delivery to within 0.01 seconds.

Waterer description and performance: The dissimilarity between the spacecraft waterer and the Laboratory Test Model waterer exists in the method of water storage. Instead of two individual water storage tanks pressurized through bladders, the water storage in the laboratory test model is accomplished by the storage of water for two primates, 302,950 grams, in a single commercial quality tank pressurized to yield 25 psig at the delivery mouthpiece. The storage tank has a fitting to permit pressurization, a fill hole that may be sealed tight, a pressure relief valve and a level gage. The tank is located outside the pressure shell. Tubes from the storage tank deliver water to each of the solenoid valves. A pressure gage is installed on the tank side of the valve to allow proper pressurization; this presumes that the gage, valve, and delivery mouthpiece are on the same level while the tank is not necessarily so.

The metering mouthpiece which is identical to the spacecraft design is motor driven. When the delivery cycle starts, the solenoid valve opens, the piston retracts, thereby filling the precision volume. The solenoid valve then closes, the shaft retracts and the piston moves forward dispensing 2 cc of water. The shaft then reseals the mouthpiece.

The design features of the Waterer, excluding the storage, are indicated by Northrop Drawing 148-11500, "Subassembly Water Supply and Dispenser."

Waterer preliminary equipment list: Table 10 represents a selection of major component items required in mechanizing the Waterer preliminary design; as noted, the units are already developed and available.

TABLE 10. - WATERER PRELIMINARY EQUIPMENT LIST

Item no.	Description	Suggested manufacturer	Part no.	Quantity per LTM
1	Planetary gear motor	Globe Industries	102A193-10	2
2	Solenoid valve	Skinner Corporation	V52DA1250	2
3	Ball bearings	New Hampshire Corporation	SR4PP	4

Behavioral panel. - The animals will be trained by the Principal Investigator to perform a number of behavioral tests which are designed to provide measurements of the tendency to eat and drink, reaction to frustration and startling, escape/avoidance of noxious stimulation, and circadian patterns of behavior, animal's ability to estimate short time intervals, reaction time, visual and auditory discrimination. In addition, an area in the primate's life cell will be needed to accomodate the waterer-primate and feeder-primate interface. A behavioral panel to provide stimulus signals for specific tasks, means for the primate to accomplish the tasks, and means of providing rewards, water and food for accomplishing the tasks, is provided to serve this function. The command and control subsystem section contains a description of the electronics associated with the panel. This panel is identical to the spacecraft behavioral panel.

Behavioral panel requirements: The following requirements shall be complied with using the behavioral panel equipment specifically designed to simulate the spacecraft behavioral panel:

(1) The behavioral panel shall present stimuli to which the animal must respond in order to obtain food and water.

(2) The behavioral panel shall present stimuli which will cue other specified activity of the animal (e.g., weighting, simulated recovery, etc.).

(3) The panel shall be located away or across from the social window.

(4) The stimulus display and handles should be located for ease of viewing and manipulating when the primate is seated before the panel.

(5) The size, spacing and positioning of stimuli and handles shall be convenient and reduce the possibility of confusion.

(6) Handles projecting 1 inch, 3/8 inch diameter, and moving upward 1/4 inch with a 3-ounce force will be provided for each task.

(7) The food mouthpiece, 5/8 inch O.D., and water mouthpiece, 1/4 inch O.D., shall be located above the handles.

(8) Stimulus lights shall surround the handles and mouthpieces.

(9) The behavioral panel shall be invulnerable to the animal's curiosity and to fouling by waste matter. This includes obstruction of indicators.

Behavioral panel description and performance: The behavioral panel design shown in figure 10 consists basically of two panels. The first panel consists of three lights - blue, red and yellow. The blue light is the stimulus illumination for the timing component (TIM), the red light is the stimulus illumination for the interlock components (ILK), and the yellow light is the stimulus illumination for the Vigilance component (VIG). A maximum possible number of eight lights per response panel component are shown. The response panel has a translucent material covering the lights and the finger levers whose bases are enclosed by an elastomer material for sealing purposes.

The waterer-feeder mouthpiece panel is the other portion of the behavioral panel. This subassembly consists of a maximum of twenty-eight white lights, a waterer moughpiece, a feerer mouthpiece, and translucent material covering the lights and providing the sealing interface for the mouthpiece exterior surfaces. Even though the maximum number of lights are shown, only one-half of the lights will be on. The lights, therefore, have redundancy built into the design.

The behavioral panel will be made water-tight by using Viton gaskets and/or a potting technique. The translucent material is used in order to allow the lights to be seen by the primate but will not allow the primate to touch the light source.

Behavioral panel preliminary equipemnt list: Table 11 lists those major items other than the electronics and panel structural material anticipated as being necessary to its mechanization.

TABLE 11. - BEHAVIORAL PANEL PRELIMINARY EQUIPMENT LIST

Item no.	Description	Suggested manufacturer	Part no.	Quantity per LTM
1	Microswitches	Minneapolis-Honneywell	11SM23	12
2	Lamp bulbs	General Electric Corporation	T-1-3/4-11-C-2F-BI-PIN	104
3	Elastomer materials	Kirkhill Rubber Company	New	6

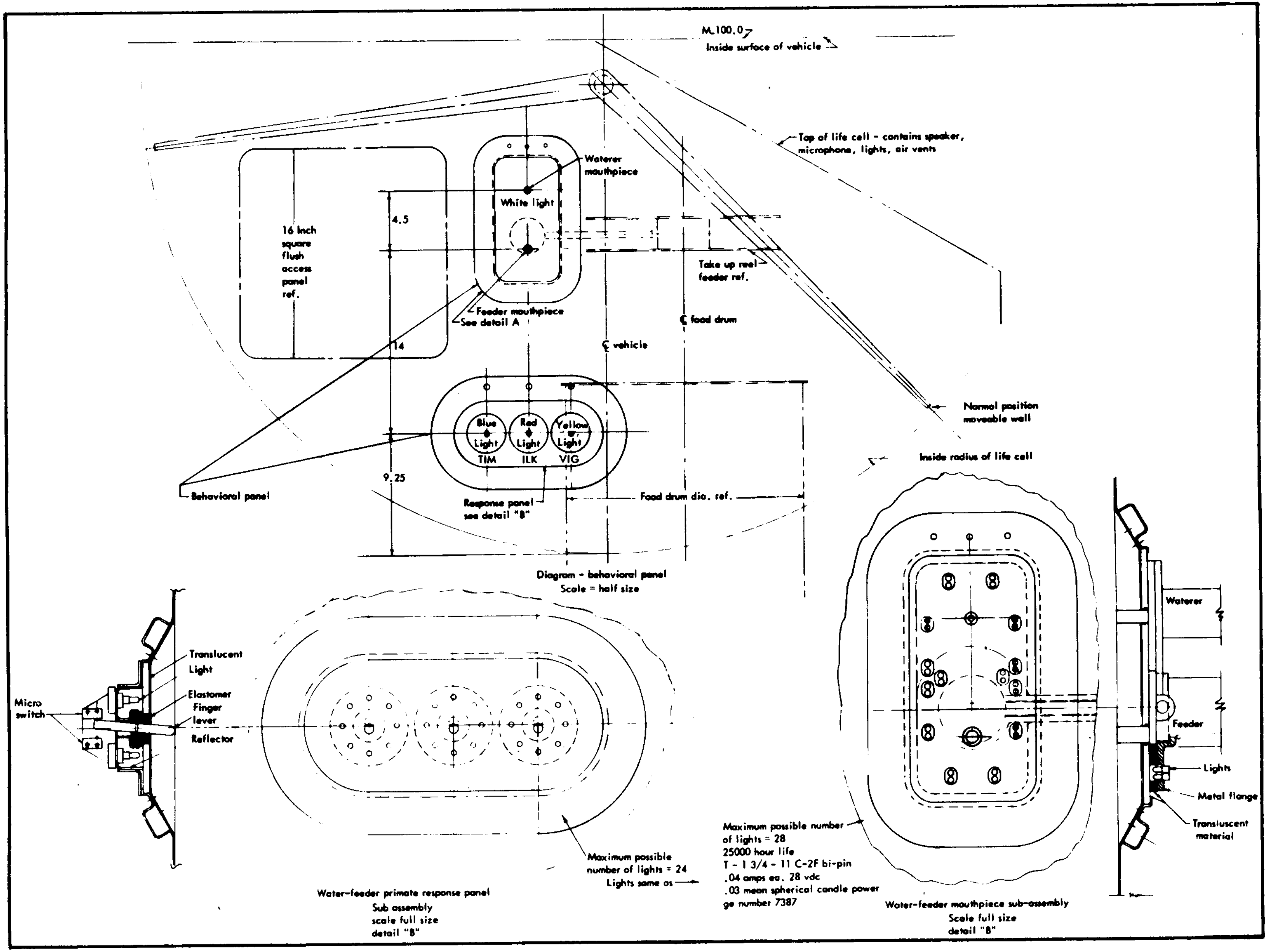


Figure 10.-Behavioral panel

Environmental control and waste management. - The environmental control subarea porvides a life supporting atmosphere for two animals according to specified requirements. All equipment used in the laboratory test model environmental control subarea is selected and instrumented to prove the design of components proposed for the Orbiting Primate Spacecraft. The differences between the Laboratory Test Model and the equipment proposed for the Orbiting Primate Spacecraft are identified in each component area described below.

Environmental control and waste management requirements: The environmental control system/waste management system functions to maintain the conditions within the primate chanber so as to assure that the primates will survive for one year.

The requirements may be summarized as follows:

(1) Handle thermal loads imposed by the primates and associated electronics.

(2) Control atmosphere level and composition to within specified limits.

(3) Remove primate generated carbon dioxide from the atmosphere.

(4) Control trace contaminants below spacecraft maximum allowable concentration limits established for manned missions.

(5) Maintain a desirable ventilation velocity.

(6) Maintain a desirable effective atmosphere temperature.

(7) Prevent dust from dried feces from spreading through the life support system.

(8) Establish the capability of handling waste material.

Environmental control and waste management description and performance: The environmental control system/waste management system description of the Laboratory Test Model is similar to the operating primate spacecraft environmental control system/waste management system. Specific differences are noted below. Figure 11 is a schematic representation of the environmental control and waste management mechanization.

Cryogenic storage techniques for the oxygen and nitrogen atmosphere will be used in the operating primate spacecraft. The laboratory test model uses high pressure commercial gas bottles for storage of oxygen and nitrogen The bottles are equipped with regulators to regulate the pressure to 50 psia and pressure indicators to indicate pressure at the life cell input valve. Pressure inside the pressure vessel is regulated to 17.0 psia with an accuracy of ±0.2 psia.

The oxygen-nitrogen selector valve and total pressure inlet valve to the pressure vessel are of the same design as proposed for the operating primate spacecraft with the exception that inlet valve is equipped with a device to insure that a fixed flow rate is maintained when it is commanded open. It will be possible to determine the amount of oxygen or nitrogen introduced into the pressure vessel from the knowledge of the position of the oxygen - nitrogen selector valve and when and how long the inlet valve is commanded open. Provisions shall be made to weigh the gas contained in the high pressure storage tank to within 0.2 lb.

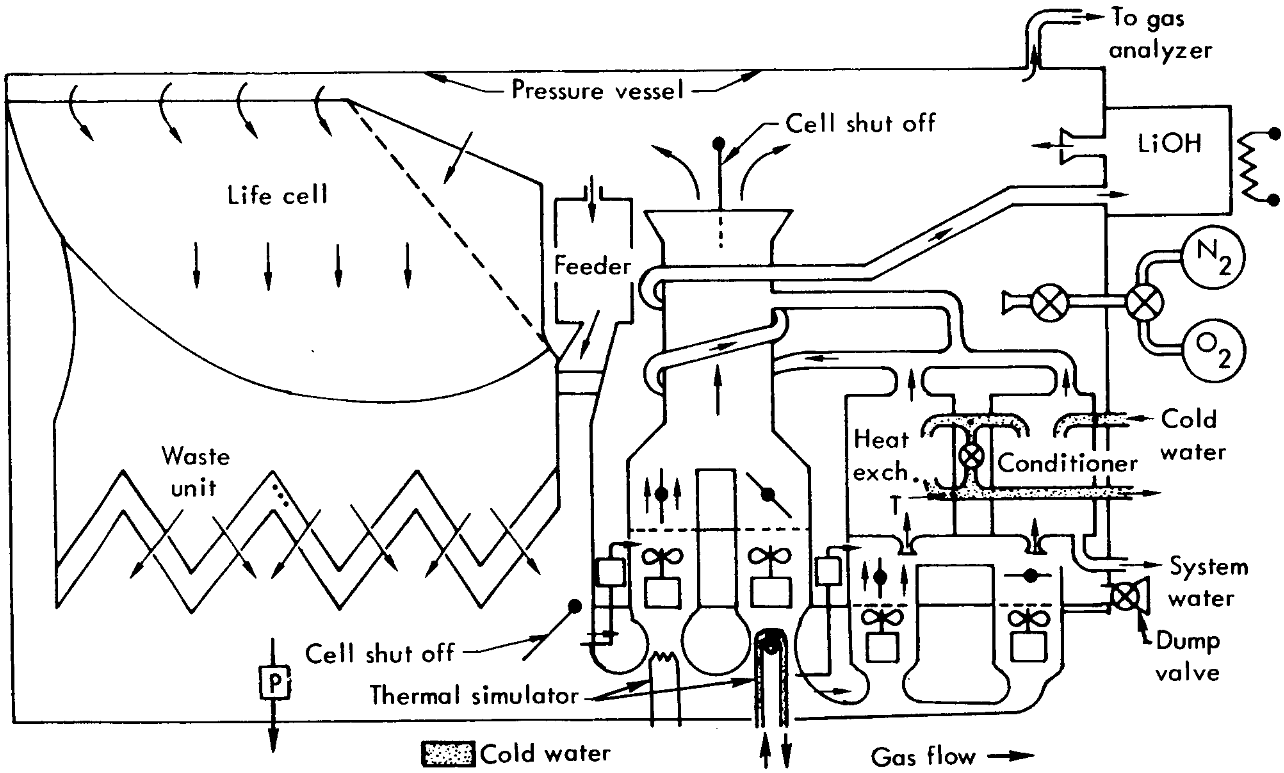


Figure 11.-LTM environmental and waste management systems

Gas analyzers are used to determine the constituents of the life cell atmosphere. The gas analyzers and gross gas analyzers are mass spectrograph type supplied as a GFE item and installed by the LTM contractor. A vacuum pump shall be connected to the gas analyzers to reduce the discharge pressure to 10^{-6} torr. Three polarographic partial oxygen pressure sensors are connected into the life support atmosphere in such a manner that only one sensor is exposed to the atmosphere at a time. These sensors are used as a backup monitor of partial oxygen pressure inside the life cell. Provisions shall be made to namually override and regulate partial oxygen pressure inside the life cell. Provisions shall be made to manually override and regulate partial oxygen pressure concentration inside the pressure vessel.

Two atmosphere dump valves will be provided. The purge dump valve is activated manually and is commanded to dump gas when the trace contaminants are in excess of the specified limits. The pressure relief valve dumps gas when pressure inside the pressure cell is 17.2 psia. Differences in the laboratory test model compared with the spacecraft are as follows:

(1) No total atmosphere dump valve is provided in the laboratory test model.

(2) The over-pressure valve is controlled to 17 ± .2 psia.

A circulation fan in the main air stream loop provides a 30 fpm velocity of the atmosphere flowing through each life cell. The 30 fpm velocity ensures transport of debris and waste from the life cell to the waste management system. Fan power is controlled by the fan controller. The down stream check valve is an integral part of the fan assembly, with the fan motor a brushless dc design, using photoelectric commutation.

The contaminant fan in the secondary air stream provides a fixed mass flow rate for processing to control humidity, temperature, and carbon dioxide concentration. The check valve is an integral part of the completed fan assembly, with the fan motor a brushless dc design, using photoelectric commutation.

The heat exchanger in the secondary air stream is of the compact plate-fin type with circulating atmosphere, 21% oxygen with nitrogen diluent, making a single pass through the core. This heat exchanger is used to transfer the sensible heat load to the Thermal Control Subsystem. The water coolant, supplied by the laboratory facility, makes two passes in the cross-counterflow direction.

The condensing heat exchanger in parallel with the sensible heat exchanger, is based upon the cross-counterflow plate fin approach. The single-pass gas passages shall include metal wicks for transport of the condensed water vapor from the airstream to a collection tank by capillary action. The condenser is used to transfer the latent heat load to the Thermal Control Subsystem.

The major difference in the heat exchangers is that cold water at 50° ± 5°F shall be used rather than FC-75 as a cooling agent. The regenerator is used to preheat a portion of the circulating secondary air stream to a temperature approximating the life cell before entering the LiOH canister. The preheating assures proper operation of the carbon dioxide removal bed. The regenerator is fabricated by welding two tubes together. One tube is straight and carries the full flow of the circulating atmosphere, while the other is a spiral tube wrapped around the straight tube. The spiral tube carries the low flow of circulating gas to be processed in the lithium hydroxide canister.

The lithium hydroxide canister, an aluminum tank located outside the pressurized section of the life cell structure, is used to absorb carbon dioxide from the primate atmosphere. It has heaters on the exterior surface to simulate the solar energy input in the Orbiting Primate Spacecraft.

The waste management subarea, identical to the Orbiting Primate Spacecraft/ waste management system consists of an aluminum framework that supports the multi-layers of graduated wire mesh in a manner to provide an extended surface filter. The aluminum framework is firmly attached to the walls of the pressure shell. An activated charcoal bed and a source of ultraviolet light also are supported within the framework below the wire mesh filters. The bed and light along with a catalytic burner in the lithium hydroxide-atmosphere loop control the level of contaminants in the atmosphere.

Environmental control and waste management preliminary equipment list: Table 12 lists the major equipment items for environmental control and waste management.

Recovery capsule. - The recovery capsule is a mockup of the one used in the Orbiting Primate Spacecraft. The capsules will provide a means of testing the primates as to their response to a signal tor a recovery phase.

Recovery capsule requirements: The recovery capsule requirement is to simulate the interior configuration of the Orbiting Primate Spacecraft capsule. Its door must be operable after one year of storage. A viewing port must be provided.

Recovery capsule description and performance: The selected configuration of the recovery capsule is shown in figure 12. The recovery capsule is connected to the life cell but separated by a door that remains closed until the capsule is used. There is no self-contained or plug-in environmental control unit in the capsule. The capsule contains a window near the top to entice the primate inside and to permit viewing of the primate after it is in. A hand hold shall be provided under the window to assist the primate's entrance into the capsule. The recovery capsule is 17.5 inches high, 22 inches long and 19 inches wide with an interior volume of 1.5 cubic feet.

Recovery capsule preliminary equipment list: Table 13 lists the major equipment items for the recovery capsule.

Thermal Control

The basic funtion of the Laboratory Test Model Thermal Control Subsystem is to remove waste heat from the pressure shell and its contents. A secondary function is to add heat as required in order to simulate transient heat loads that may be required during test operations. The Orbiting Primate Spacecraft Thermal Control Subsystem utilizes surface radiation to transfer that (radiation mode) to the deep spare sink. An active FC-75 coolant loop is used as an intermediate link in the heat path between the heat products, animals, electronics, etc., and the surface radiation. The Laboratory Test Model Thermal Control Subsystem eliminates the FC-75 coolant loop and substitutes a water heat transfer unit loop. Insulation is also provided over the entire Laboratory Test Model to assure that all heat leaves through the water loop. Thermal simulation in the form of strip heaters and water cooling coils are also provided to simulate transient loads.

TABLE 12. - ENVIRONMENTAL CONTROL/WASTE MANAGEMENT PRELIMINARY EQUIPMENT LIST

Item No.	Description	Suggested manufacturer	Part No.	Quantity per LTM
1	Circulation fan	AiResearch Manufacturing Co.		2
2	Fan Controller	AiResearch Manufacturing Co.		2
3	Contaminant fan	AiResearch Manufacturing Co.		2
4	Heat Exchanger	AiResearch Manufacturing Co.	812000-M	1
5	Condenser	AiResearch Manufacturing Co.	81300-1	1
6	Heat exchanger bypass valve	AiResearch Manufacturing Co.	132636-M	2
7	Carbon dioxide removal unit	AiResearch Manufacturing Co.		1
8	Pressure relief valve	AiResearch Manufacturing Co.	630006-4	1
9	Oxygen/nitrogen selector valve	AiResearch Manufacturing Co.	9000060-1	1
10	Total pressure regulator	AiResearch Manufacturing Co.	828510-2	1
11	Catalytic burner	AiResearch Manufacturing Co.		1
12	Purge valve	AiResearch Manufacturing Co.	829130	1
13	Waste management unit	AiResearch Manufacturing Co.	829130	2
14	Gross gas analyzer	Perkin Elmer Co. (GFE)		1
15	Fine gas analyzer	Melpar Corporation		1
16	Cell shut-off valve	Northrop Corporation		1
17	Gas flow meters	AiResearch Manufacturing Co.		8
18	Butterfly valves - 2 inches 4 inches	AiResearch Manufacturing Co.		 2 2

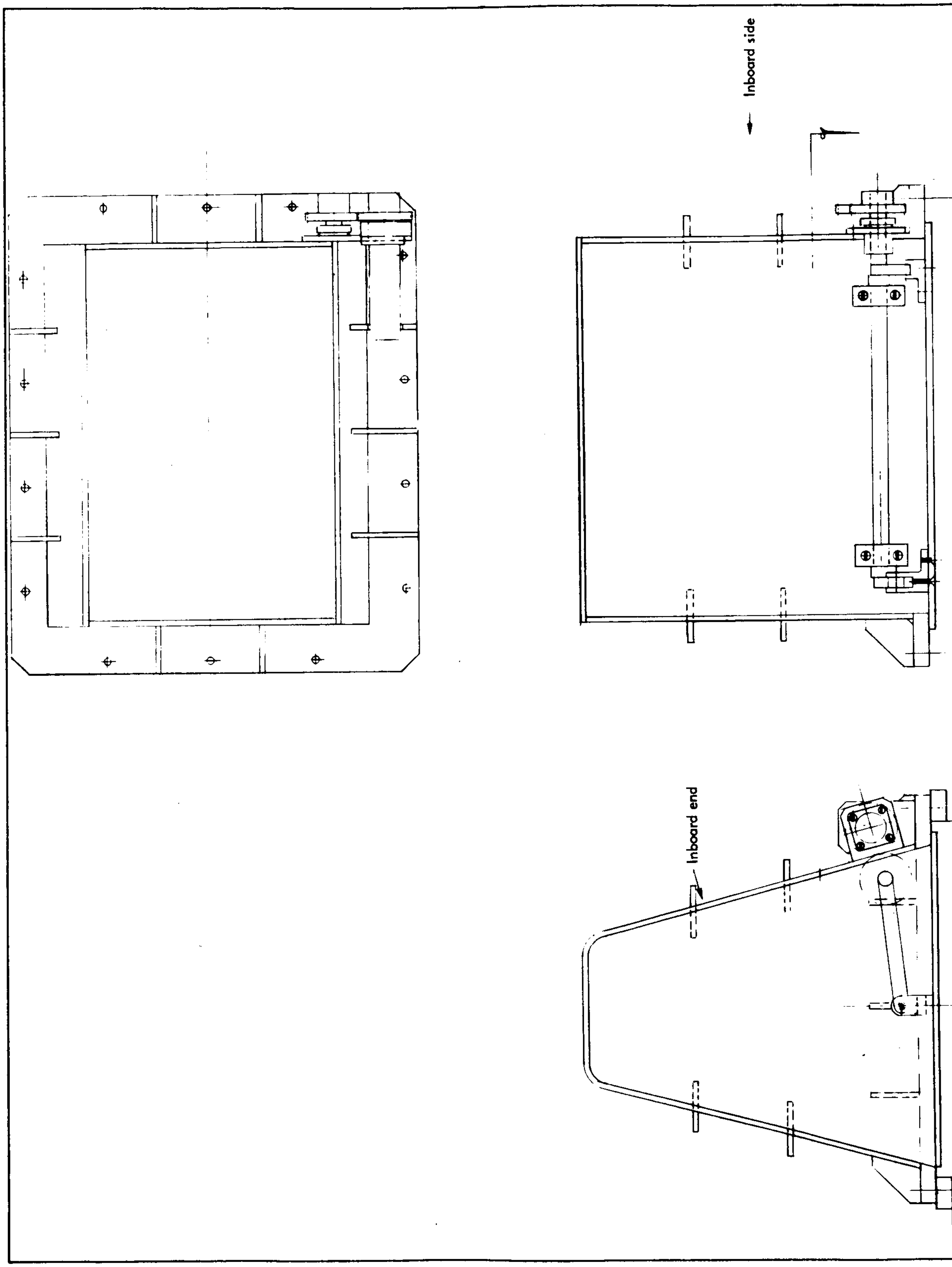


Figure 12. –Recovery capsule

TABLE 13. - RECOVERY CAPSULE PRELIMINARY EQUIPMENT LIST

Item No.	Description	Suggested manufacturer	Part No.	Quantity per LTM
1	Pressure envelope	Northrop Corporation	New	2
2	Door assembly	Northrop Corporation	New	2
3	Door actuator assembly	Northrop Corporation	New	2
4	Gear motor	Globe Industries	102A152-11	2
5	Door latch assembly	Northrop Corporation	New	2
6	Cam latches	Northrop Corporation	New	8

Thermal control requirements and constraints. - The Laboratory Test Model Thermal Control Subsystem is constrained to operate in an air conditioned laboratory, air temperature; 70± 5°F, R.H.; 50±10% for a period of one year. Requirements for this subsystem are as follows:

(1) One year lifetime.

(2) Handle steady state head loads and variations while maintaining temperatures within design limitations, life cell temperature 73 ± 4°F.

(3) Supply heat to simulate transient loads as required.

(4) Insulate pressure shell from laboratory environment.

Water heat transfer unit: The Laboratory Test Model Water heat transfer unit consists of the plumbing, stainless steel tubing, required to carry laboratory supplied cooling water at 50 ± 5°F, at a rate of 10 gallons per hour to and from the Laboratory Test Model Environmental Control System heat exchange and condenser units. Figure 13 shows in schematic form the water flow paths. The water passes through these two units in a manner similar to the Orbiting Primate Spacecraft system except that after passing through the heat exchanger and/or bypass valve, the liquid is directed through a flow meter and dumped into the laboratory sewer drains. A flow control valve is installed upstream of the Environmental Control System condenser to maintain a constant 10 gallon per hour flow rate.

Insulation: Thermal insulation in the form of a blanket will be provided over the entire Laboratory Test Model. The blanket will be supported on a light plywood frame that can easily be removed while testing is in progress. Since the bulk of the heat producing electronics is located external to the Laboratory Test Model in the test rack, the insulation blanket serves as a heat barrier should laboratory environmental conditions vary excessively during the test period. In addition, the insulation serves as a noise barrier by reducing the noise level presented to the animals from the laboratory to below audible limits.

The blanket itself consists of two inches of Min-K super insulation loosely packed between two layers of 5 mil aluminized mylar. The blanket is sewn together with nylon thread and cutouts are provided for gas and liquid lines. The blanket is attached to the plywood support by means of phenolic standoffs and steel bolts. Figure 14 shows a cross section of the blanket, and figure 15 depicts the insulation installed over the Laboratory Test Model. As figure 15 shows, one face of the insulation support is hinged to allow lateral installation of the insulation assembly.

Thermal simulation: In order to provide versatility to the test in regard to transient heat loads, strip heaters will be provided to simulate such items as heat producing electronics, etc. They will consist of commercial 28 v.d.c. heater pads cemented to blocks of aluminum that equal the mass of the devices that they are replacing. Laboratory power sources, switching devices and power measuring equipment will be used to activate and monitor the heaters. In addition, a cooler in the form of a coil of stainless steel tubing will be

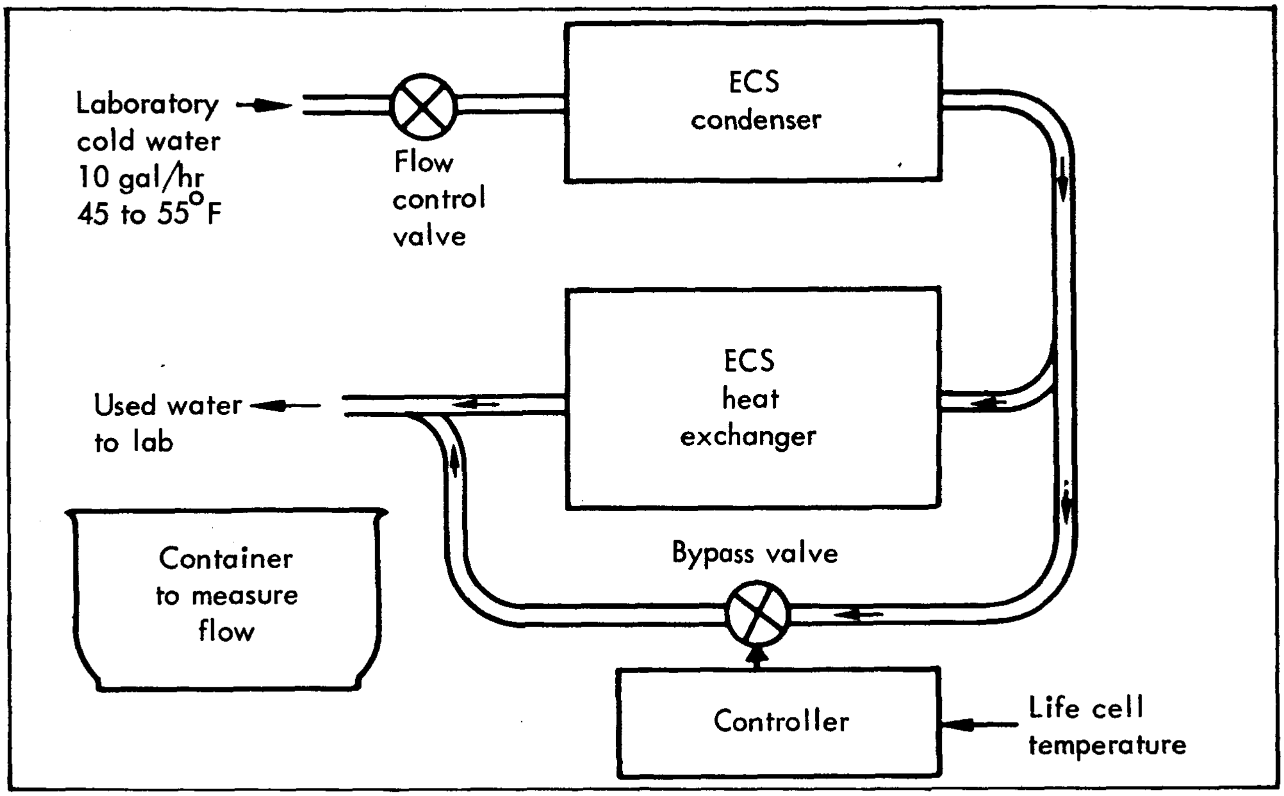


Figure 13.–ECS cold water flow

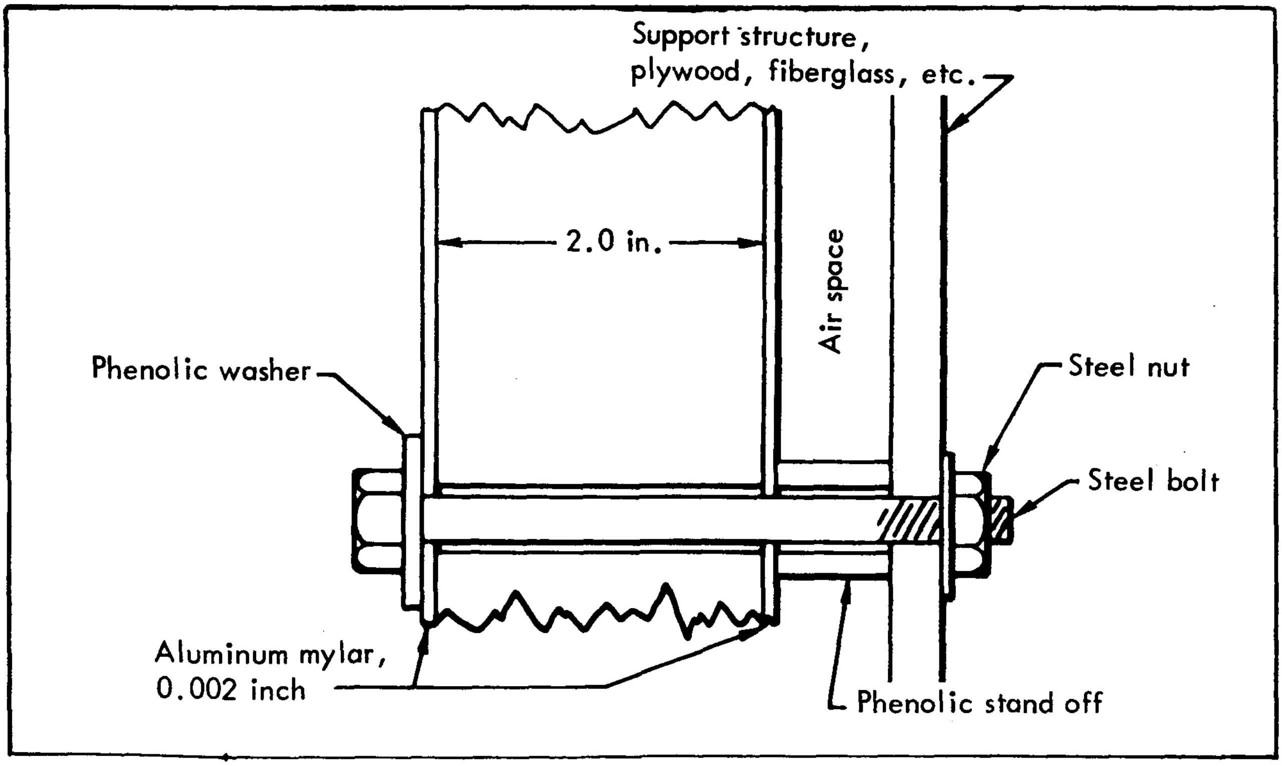


Figure 14.–Cross section of insulation blanket

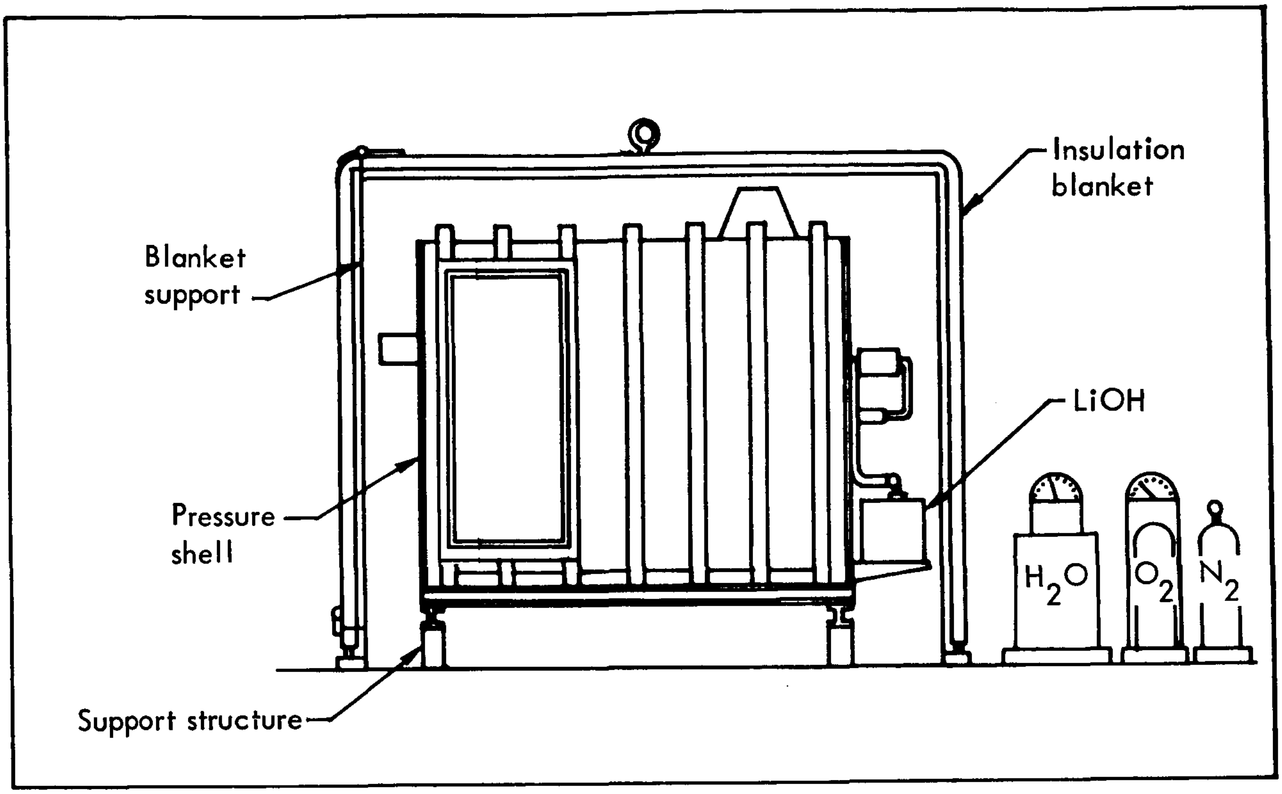


Figure 15.– Pressure vessel insulation

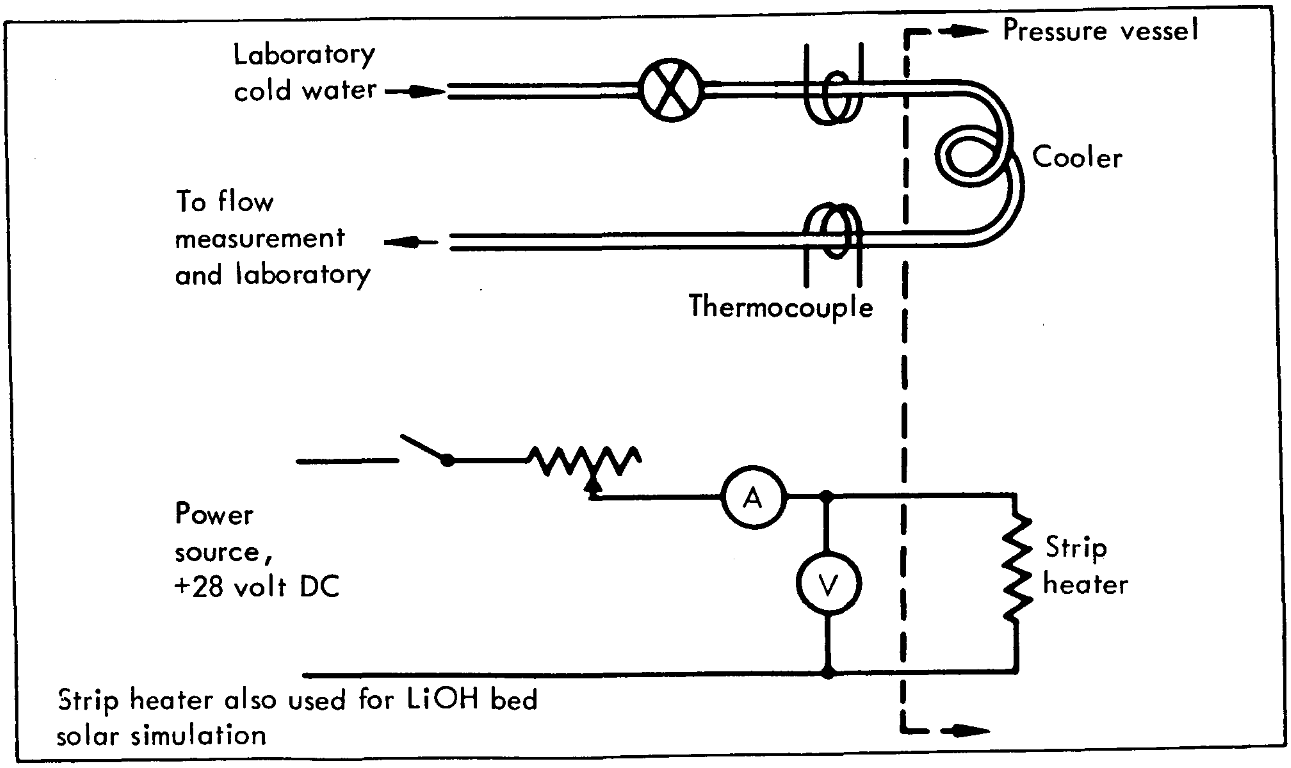


Figure 16.–Thermal simulator

installed in the main Environmental Control System air duct to simulate a transient cooling load. The cooling coil will be fed with chilled laboratory water controlled by a valve just upstream of the coil. Before being dumped in the lab sewer system the water will be fed to a flow measuring device. Thermocouples on either side of the coil will indicate the rate of cooling provided to the Laboratory Test Model. Figure 16 shows a schematic of the thermal simulators.

Thermal control subsystem preliminary equipment list. - Table 14 lists the equipment required for the Laboratory Test Model Thermal Control Subsystem.

TABLE 14. - LABORATORY TEST MODEL THERMAL CONTROL

SUBSYSTEM PRELIMINARY EQUIPMENT LIST

Item No.	Description	Suggested Manufacturer	Part No.	Quantity per Model
1	Stainless steel tubing	AiResearch		As required
2	Flow control valve	AiResearch		1
3	Bypass valve	AiResearch		1
4	Flow measuring device	Veeder-Root		1
5	Min K insulation	Johns Manville		As required
6	5 mil mylar	G. T. Schjeldall		As required
7	Phenolic standoffs	Northrop		As required
8	Plywood blanket support	Northrop		1
9	Strip heater	Northrop		As required
10	Stainless steel cooling coil	Northrop		1

Structure and Mechanical

The basic function of the Laboratory Test Model Structure and Mechanical Subsystem is to provide a gas tight envelope around the animal life cells and certain portions of the Environmental Control System. In addition, it provides structural support for and accessibility to the other subsystems and indirectly to the animals. In developing the Laboratory Test Model pressure shell, no attempt was made to follow the design of the Orbiting Primate Spacecraft shell except where a direct interface with the animals resulted. In fact, the basic Laboratory Test Model shell was designed with flat sides and external bracing in order to reduce the complexity of manufacture and during actual testing, the complexity of accessibility. In addition to the pressure shell, a supporting structure completes the subsystem.

Structure and mechanical constraint requirements. - The Laboratory Test Model Structure and Mechanical Subsystem is constrained to operate in a one g environment while installed in an air conditioned laboratory facility. While operating under this constraint, the Structure and Mechanical Subsystem is required to:

(1) Provide support and protection for all experiment and other subsystem elements.

(2) Provide a pressure shell capable of containing the life cell assemblies and Environmental Control System units, excluding primary and secondary fans and lithium hydroxide canister, that will operate at a 5.0 psig maximum pressure differential.

(3) Provide access, during testing, to the main and secondary Environmental Control System fans, the food pellet dust filter, the gas analyzer and the television cameras.

(4) Provide an inert inside surface finish.

(5) Provide a one year operating lifetime.

Pressure shell. - The general arrangement of the Laboratory Test Model pressure shell is shown in figure 17. The basic shell consists of 0.25 inch thick 6061T6 aluminum plate 100% penetration welded together to form a 94.5 inch long by 74 inch high by 76 inch wide rectangular box. Located on each end of the basic box is a 17.5 inch long by 67 inch high by 34 inch wide feeder cover. Both feeder covers are constructed in the same manner as is the basic shell. However, the covers are bolted to the basic shell using Viton gaskets for an airtight seal. Four inch T sections are welded on ten inch centers around the outside shell surfaces to form tension hoops. The basic shell is designed for a maximum pressure differential of 5.0 psig assuming that the atmosphere pressure inside the shell is held at a constant 17.0 psia and atmospheric pressure could drop as low as 12.0 psia. At the maximum pressure differential, the leakage rate will not exceed 0.2 pounds per day, and deflector of any portion of the largest single flat panel will not exceed 0.1 inch.

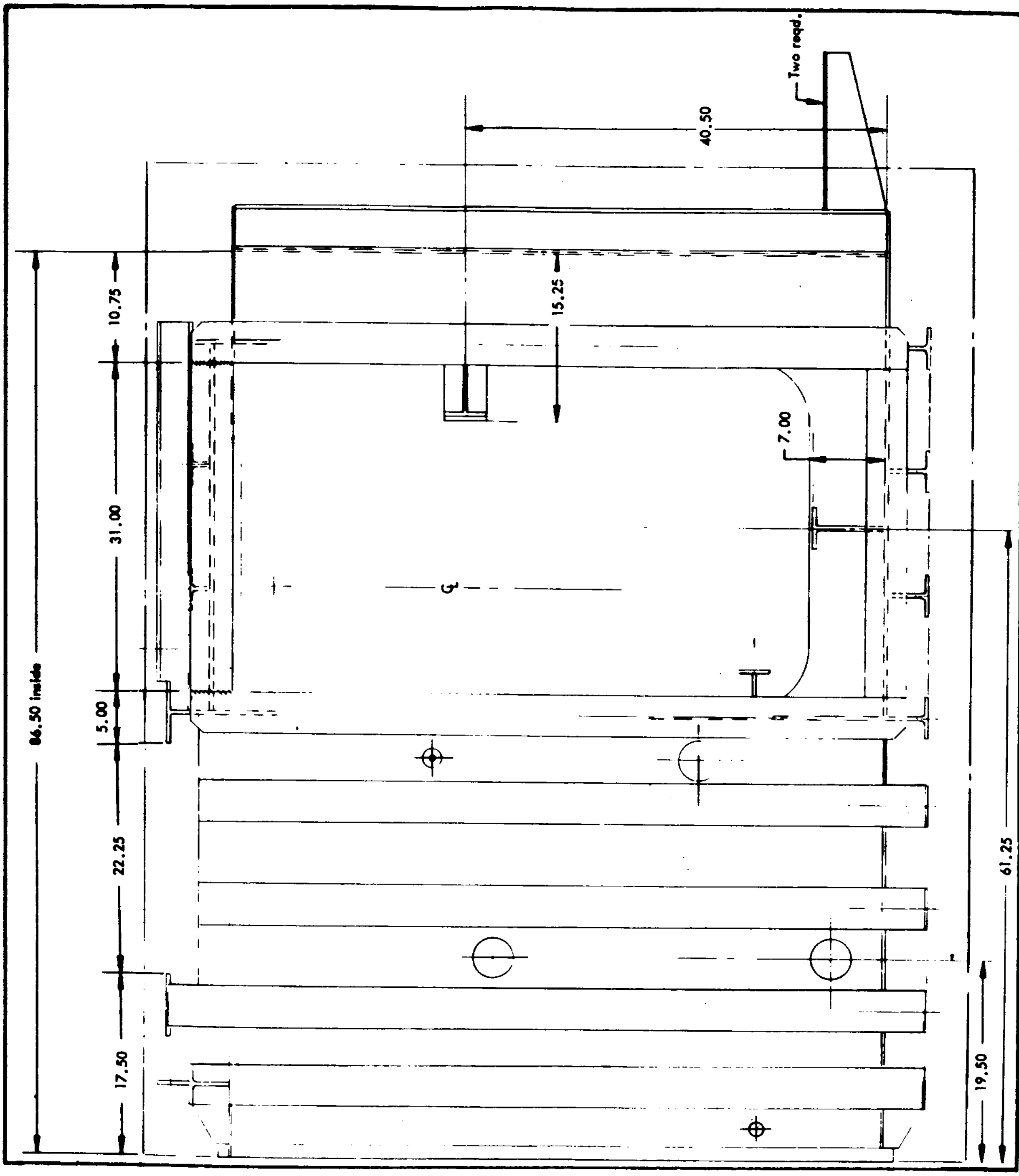


Figure 17. - Laboratory test model assembly

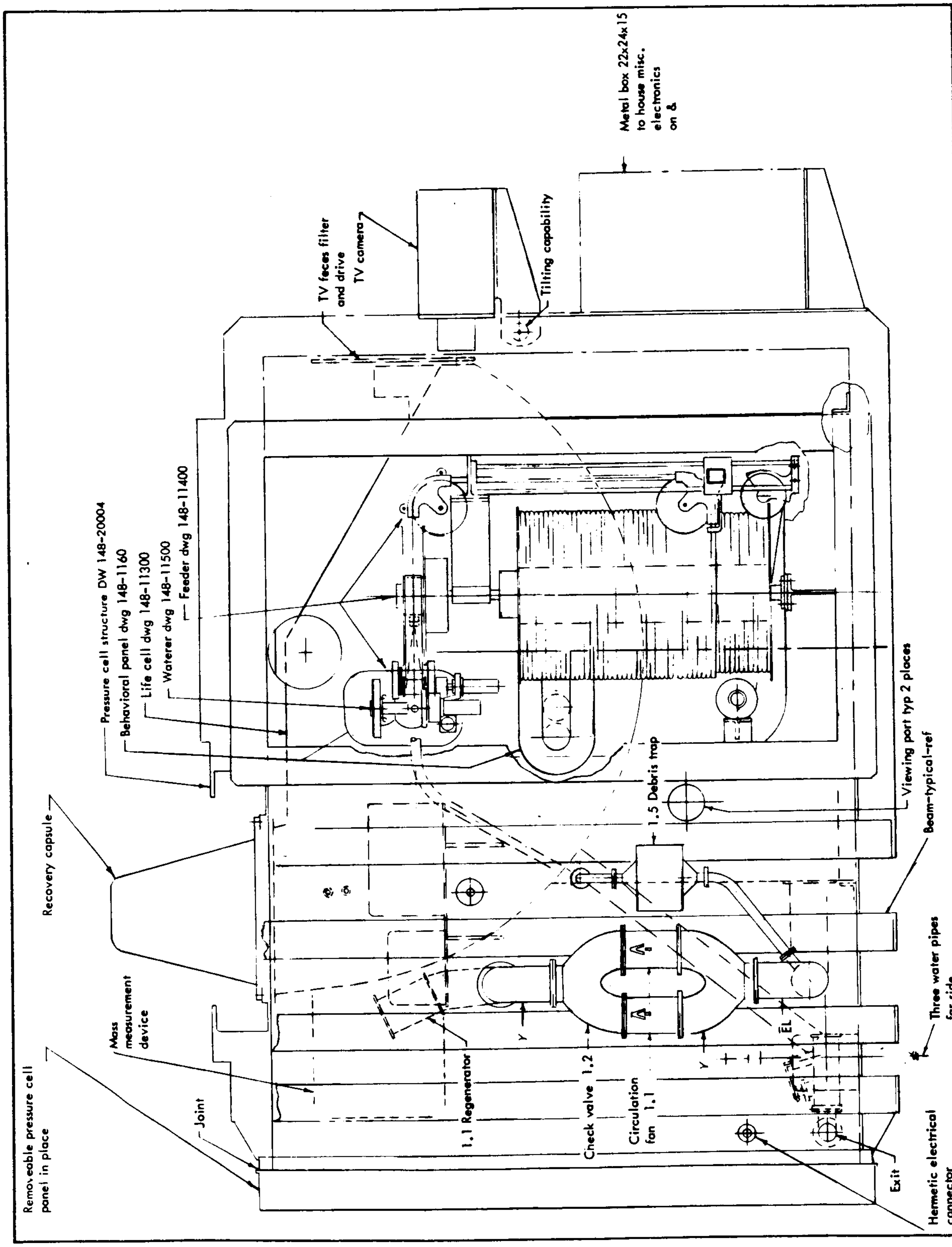


Figure 17. - Laboratory test model assembly

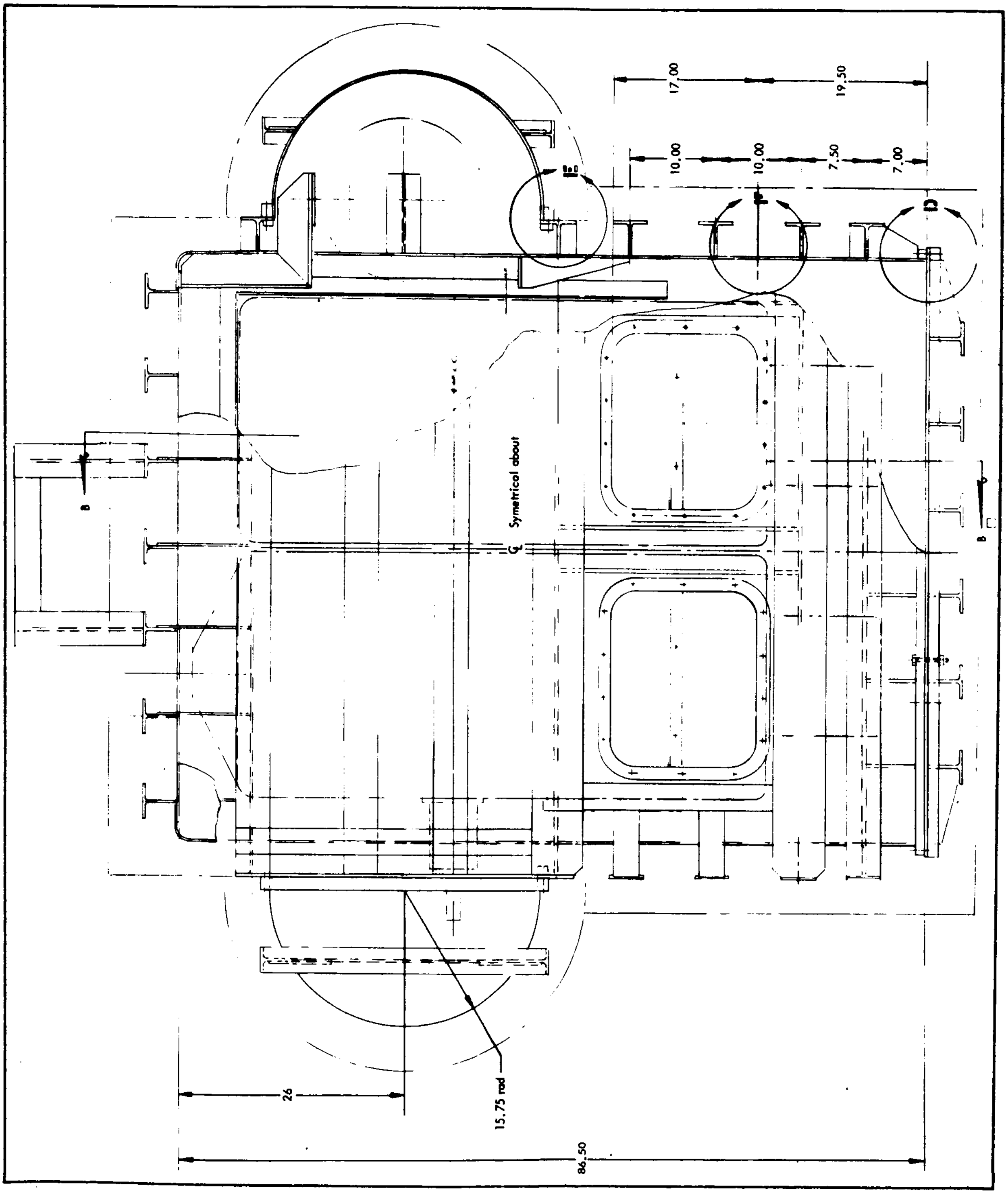


Figure 17. - Laboratory test model assembly

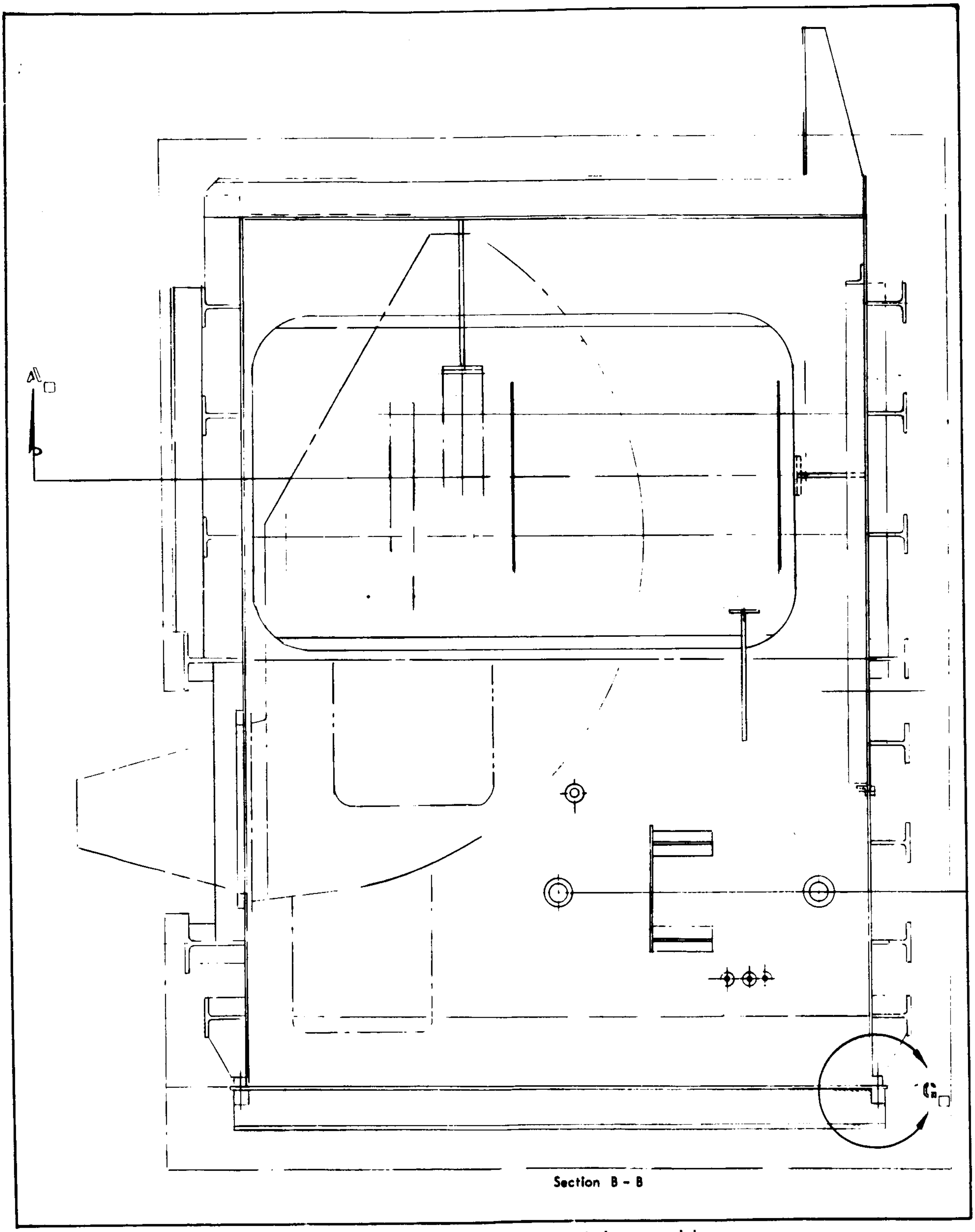


Figure 17. - Laboratory test model assembly

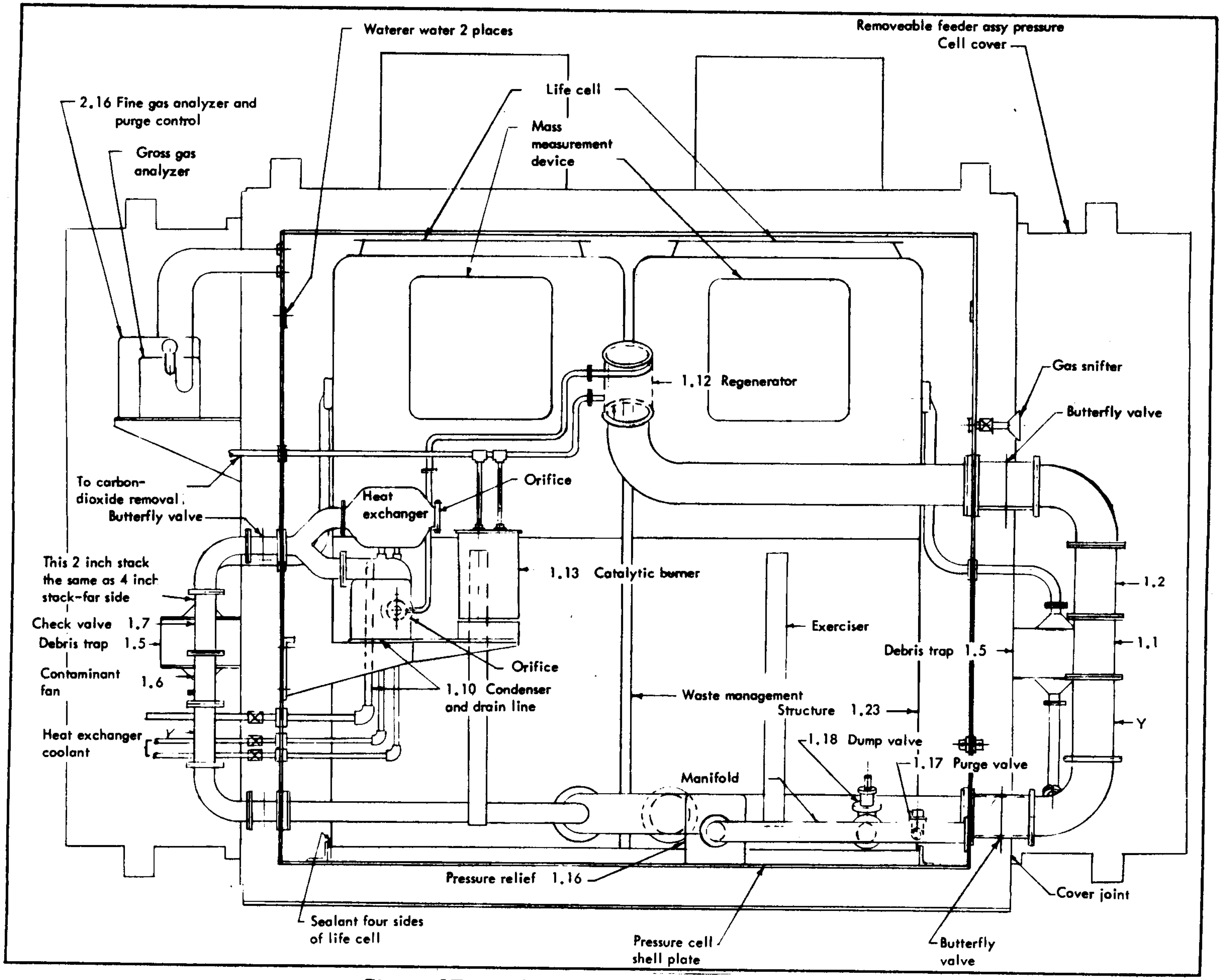


Figure 17.– Laboratory test model assembly (concluded)

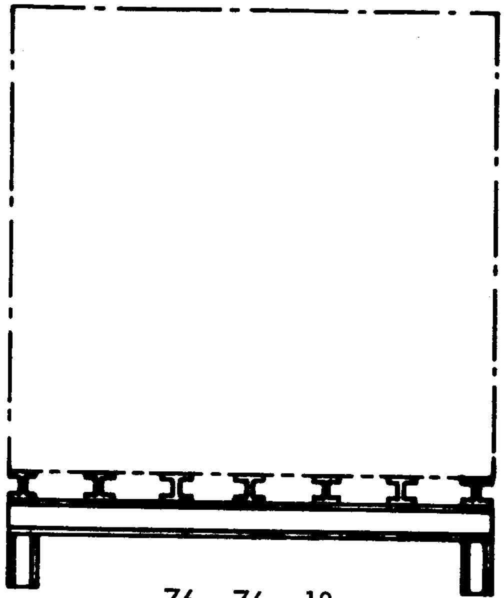
Additional features of the basic shell are two cutouts on the top face that exactly match the recovery capsule flange patterns and a completely removable side face. Entry into the life cells will be possible through the recovery capsule cutouts while the complete life cell assembly can be installed and removed through the open face. Finally, all liquid and gas lines and electrical conductors into the life cells are routed through the pressure shell wall using air tight connectors. This also includes the ducting carrying breathing atmosphere to and from the four Environmental Control System fans. Isolating butterfly valves are provided in the manifolds at each end of the fan assemblies thereby making it possible to remove and replace these fans while the test is in progress. In order to prevent atmospheric contamination, all internal surfaces of the pressure shell will be hard anodized.

Supporting structure. - The Laboratory Test Model supporting structure consists of a welded steel assembly of five inch H section junior beams. The beams are spaced on 24 inch centers to form a grid which supports the floor of the pressure shell. The grid itself is supported 18 inches off the floor of the laboratory facility using four beam legs. This allows access to the bottom of the pressure shell through the supporting structure grid. The entire structure, including the exterior surface of the pressure shell, will be painted with a rust inhibiting paint capable of providing protection for a minimum of three years. Figure 18 depicts the supporting structure with the pressure shell mounted on top.

Structure and mechanical preliminary equipment list. - Table 15 lists the equipment comprising the Laboratory Test Model Structure and Mechanical Subsystem.

TABLE 15. - STRUCTURE AND MECHANICAL PRELIMINARY EQUIPMENT LIST

Item No.	Description	Suggested Manufacturer	Part No.	Quantity per model
1	Pressure shell	NSL		1
2	Viton gasket for pressure shell face	NSL		1
3	Pressure shell removable panel	NSL		1
4	Shelf for condenser	NSL		1
5	Shelf for gas analyzers	NSL		1
6	Angle bracket to hold life cell	NSL		2
7	Feeder removable cover	NSL		2



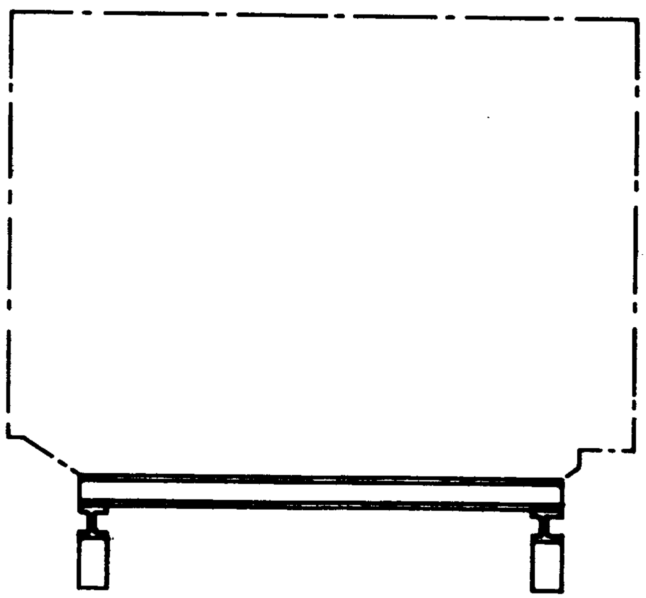


Figure 18.– Supporting structure with pressure shell mounted on top

TABLE 15. - (concluded)

Item No.	Description	Suggested Manufacturer	Part No.	Quantity per model
8	Feeder cover viton gasket	NSL		2
9	T. V. camera bracket	NSL		2
10	Electronics control box	NSL		1
11	2" fan isolating butterfly valves			2
12	4" fan isolating butterfly valves			2

Instrumentation

The Laboratory Test Model Instrumentation Subsystem consists of two television cameras and recorders, two activity counters, two biotelemetry receiving systems, two mass/volume measurement devices, miscellaneous primate and engineering sensors, strip chart, event, and temperature recorders, and miscellaneous support equipment required to maintain the instrumentation electronics.

Instrumentation requirements and constraints. - In general, the instrumentation will sense all parameters necessary to evaluate the life support equipment performance during the laboratory test phase in order to predict performance for one year in space. Monitoring of the primates by television and other means is also a prime requirement. All equipment will be capable of unattended operation for up to 24 hours for a period of one year except for occasional replacement of expendables.

Television. - Each life cell shall be provided with an externally mounted television camera. In addition to the viewport for the camera, two additional viewports shall be provided for observations and picture taking.

(1) A commercially available camera shall provide 10 frames/seconds at 250 lines per frame.

(2) The camera shall view the life cell through glass suitable for photographic work.

(3) The camera and its viewport shall be thoroughly shielded from laboratory light, both to prevent reflections into the television and to prevent the animal viewing the laboratory.

(4) The camera shall be easily moved or removed to facilitate direct viewing.

(5) The television images may be selected and viewed in real time on a video monitor and/or recorded on a video recorder.

(6) The television shall be aimed at the point where the animal's head will be when it is operating the panel. The camera shall be equipped with an 80° wide angle lens and a 10° narrow angle lens for proper viewing of the animal.

(7) A viewport shall be placed in the ceiling and one in the Waste Unit. The port in the Waste Unit shall be shielded by an awning against a straight stream of urine.

(8) The viewports shall be of a glass suitable for photographic work and shall be two inches in diameter and inserted into a threaded metal ring that would be screwed into the wall. This facilitates removal for cleaning.

(9) Provisions shall be made for making magnetic tape recording of the television pictures.

(10) The television pictures shall comply with the following requirements:

(a) The lighting system shall furnish 25 foot-candles of illumination for 14 hours.

(b) The lighting system shall furnish 0.1 foot candle of illumination for the remaining 10 hours per day.

(c) The photoperiod of 14 hours on and 10 hours off shall be changed to 24 hours on upon command.

(d) The television camera shall provide 250 line, 10 frame per second displays.

(11) Television pictures shall provide 8 shades of gray.

Audio. A microphone shall be provided for each animal cage to monitor the vocalization of the animal and the background noise in the cage. Provisions shall be made to record this noise when television pictures are being taken. Provisions shall be made to connect the microphone output to a speaker on the command and control console. Provisions shall be made to determine the amount of gain contributed by the amplifier between the microphone and the speaker or television recorder.

Calibration charts for the audio system and equipment shall be provided so that the noise level in db can be determined. The frequency range of interest is 20 to 20,000 Hz with linear response from 50 to 12,000 Hz acceptable.

Activity instrument. - The three biotelemetry receivers shall be routed to strip chart recorders as indicators of activity.

Biotelemetry receivers. - Each life cell shall be equipped with three receiver systems to receive data transmitted by telemetry transmitters implanted in the animal. The characteristics of the transmittal signal will be defined when the biotelemetry implants are selected.

The biotelemetry receivers shall be designed to receive and demodulate the transmitted data.

The antenna system shall be three Ferrite antennas orthogonally mounted in the Life Cell and protected by ceramic covers.

The receivers shall be of the superheterodyne type equipped with demodulated signal and AGC outputs. The AGC and signal outputs shall be amplified to provide driving signals for AGC recorders and to drive the strong signal select box.

The strong-signal-select box shall use the AGC voltage from the three receivers to select the most strongly received signal for use as the data signal.

The animal's heart rate is 257 + 31 bpm with a range of 160 to 333 bpm. Temperature is in the range of 95 to 105°F.

(1) Electrocardiograph shall be monitored for five minute periods six times per day.

(2) The ECG waveform shall be reproduced with sufficient fidelity to permit measurement of the intervals and amplitudes depicted by figure 19 within 0.01 second and 0.1 millivolt, respectively.

(3) Temperature resolutions shall be 0.1°C maximum and long term accuracy shall be 1°C maximum.

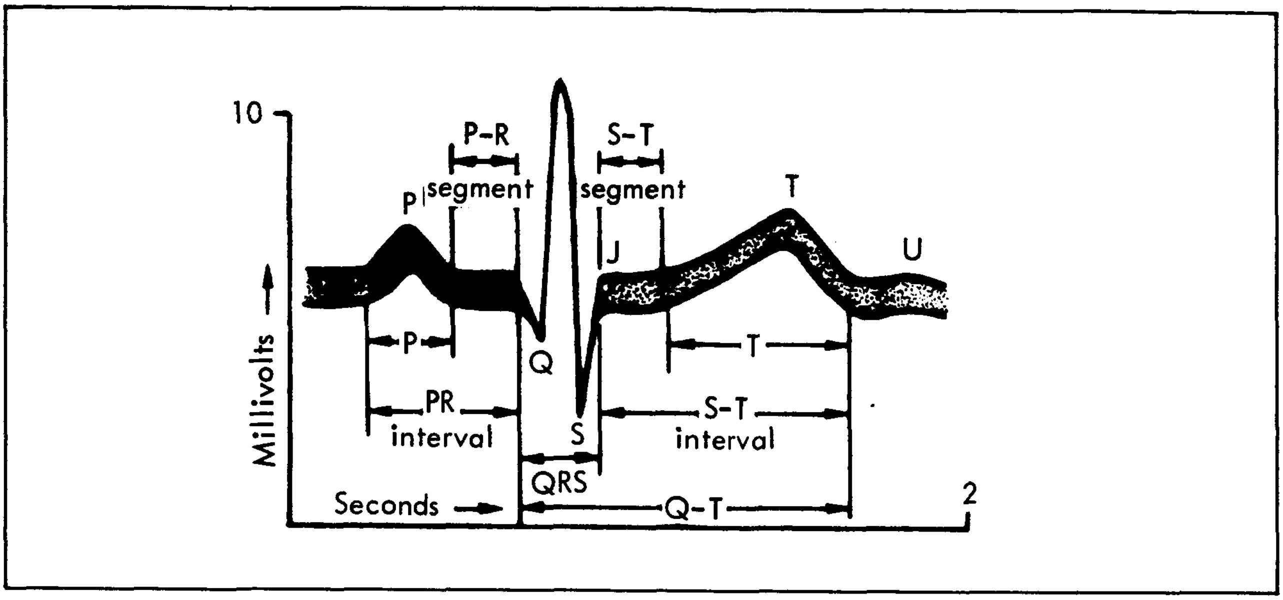


Figure 19.– ECG waveform

Sensors.- Instrument transducers shall be furnished to provide the instrumentation identified in table 16, Laboratory Test Model Measurements Requirements Analysis. The following types of transducers shall be provided with the appropriate mounting brackets, feed-through connectors and signal conditioner equipment.

Temperature transducers: Temperature transducers shall be of the thermocouple, chromel construction, type with the exception of measurements where special temperature displays are required. The thermocouples shall be connected through appropriately temperature compensates switch boxes to a multipoint recorder in a manner that provides one recorded reading of each temperature point once or more per hour. Appropriate thermocouple reference junctions shall be used as calibration points.

Humidity transducers: Humidity shall be determined by two methods. Two thermocouples shall be placed in the airstream before the life cell and two after the waste unit. One of each of the pairs shall be encased in a fabric sack kept moist through a wick. These pairs of thermocouples yield wet and dry bulb temperatures from which relative humidity may be determined. In addition to the thermocouples, a Perkin/Elmer Mass Spectrograph shall determine the water vapor content of the air upstream of the life cell.

Load cells: The load cells are used in two applications, weighing the animals and weighting the oxygen and nitrogen supplies. A single load cell, Dillon Series 0-15 pounds, calibrated in compression, shall be used to weigh the animal. The load cell shall be mounted under a box that is restricted to vertical motion by five flexures. A load cell, Dillon Series 0-30 pounds calibrated in tension, shall be used to weigh oxygen with an identical unit for weighing nitrogen. The oxygen and nitrogen bottles shall be supported

TABLE 16. - LABORATORY TEST MODEL MEASUREMENTS REQUIREMENTS ANALYSIS

Parameter	Range	Sensor type	Location	Qty.	Time basis (sample)	Acquisition method	Channels required
Temp.	60-120°F	Thermo-couple	Waste unit (20 ea)	40	1/hr.	Printout recorder	40
	50-120°F	Thermo-couple	LiOH bed	10	1/hr.	Printout recorder	10
		Thermo-couple	LiOH bed gas inlet	1	1/hr.	Printout recorder	1
		Thermo-couple	LiOH bed gas outlet	1	1/hr.	Printout recorder	1
		Thermo-couple	Heat exch. gas inlet	1	1/hr.	Printout recorder	1
		Thermo-couple	Condenser gas outlet	1	1/hr.	Printout recorder	1
		Thermo-couple	Heat exch. gas outlet	1	1/hr.	Printout recorder	1
		Thermo-couple	Condenser coolant outlet	1	1/hr.	Printout recorder	1
		Thermo-couple	Heat exch. coolant outlet	1	1/hr.	Printout recorder	1
		Thermo-couple	Condenser coolant inlet	1	1/hr.	Printout recorder	1
		Thermo-couple	Life cell (wet and dry)	4	1/hr.	Printout recorder	4
		Thermo-couple	WU outlet (wet and dry)	2	1/hr.	Printout recorder	2
		Thermo-couple	Feeder vacuum cleaner	2	1/hr.	Printout recorder	2

TABLE 16. - (continued)

Parameter Range	Sensor type	Location	Qty.	Time basis (sample)	Acquisition method	Channels required
	Thermo-couple	Gas regenera-tor	1	1/hr.	Printout recorder	1
	Thermo-couple	Main fan out-let	1	1/hr.	Printour recorder	1
	Thermo-couple	Main gas re-generator out-let	1	1/hr.	Printout recorder	1
Gas flow rate	Rotary meter	LiOH bed outlet	1	1/hr.	Digital counter	1
	Rotary meter	Waste unit outlet	2	1/hr.	Digital counter	Share
	Rotary meter	H/E inlet	1	1/hr.	Digital counter	Share
	Rotary meter	Condenser in-let	1	1/hr.	Digital counter	Share
	Rotary meter	Feeder vacuum cleaner	2	1/hr.	Digital counter	Share
	Rotary meter	Main circula-tion	1	1/hr.	Digital counter	Share
Pressure O_2	Electro-lyte	Life cell in-let plenum	1	1/hr.		1
	Perkin/ Elmer	Life cell inlet	1	1/hr.		1
Pressure N_2	Perkin/ Elmer	Life cell inlet plenum	Share	1/hr.		Share

TABLE 16. - (continued)

Parameter	Range	Sensor type	Location	Qty.	Time basis (sample)	Acquisition method	Channels required
Pressure CO_2		Perkin/ Elmer	Life cell inlet plenum	Share	1/hr.		Share
Water content		Perkin/ Elmer	Life cell inlet plenum	Share	1/hr.		Share
Vacuum		ion gage	Perkin/Elmer vacuum source	1	Contin- uous	Visual moni- tor alarm	1
Pressure		Strain gage trans- ducer	Across main fans	1	1/hr.	Oscillograph	1
		Strain gage trans- ducer	Across contam. fans	1	1/hr.	Oscillosgraph	1
		Strain gage trans- ducer	H/E coolant in to out	1	1/hr.	Oscillograph	1
Video		Camera	Life cell	2	As req'd	Video tape/ monitor	1
Sound		Micro- phone	Life cell	2	As req'd	Loudspeaker/ recorder	1
Animal Temp.		Antenna	Primate implant	2	As req'd	Meter/recorder	2
Animal position		AGC	Primate implant	2	Continu- ous	Recorder	2
Valve position		Switch	Gas flow control valve	7	Continu- ous	Event recorder	7

TABLE 16. - (concluded)

Parameter	Range	Sensor type	Location	Qty.	Time basis (sample)	Acquisition method	Channels required
Door position		Poten-tiometer	Life cell door	2	Continu-ous	Meter	2
Door position		Poten-tiometer	M/UMD	2	Continu-ous	Meter	2
Function		Photo-cell	Feeder star wheel	2	Continu-ous	Event/time totalizer	2
		Switch	Waterer Plunger	2	Continu-ous	Event/time totalizer	2
	On-off	Switch	TE handle	2	Continu-ous	Event/time totalizer	2
	On-off	Switch	ILK handle	2	Continu-ous	Event/time totalizer	2
	On-off	Switch	Exercise	2	Continu-ous	Event/time totalizer	2
	On-off	Lamp	Blue stim-ulus	2	Continu-ous	Event/time totalizer	2
	On-off	Lamp	Yellow stimulus	2	Continu-ous	Event/time totalizer	2
	On-off	Lamp	Red stim-ulus	2	Continu-ous	Event/time totalizer	
	On-off	Lamp	Reward light	2	Continu-ous	Events recorder	2
Weight	4-8 Kg	Load cell	M/V MD	2	As req'd	Digital Voltmeter	1
	0-25 lb.	Load cell	O_2 and N_2	2	As req'd	Digital voltmeter	Share

on their sides on a small platform, one side of the platform shall be supported on a stainless steel knife edge and the other on two stainless steel springs. The load cell shall be attached to the spring edge and will record the weight of the gas used. The above three load cells shall be furnished power and provide inputs to a Dillon Type B Power Supply. This device properly conditions the load cell output and supplies an input to a digital voltmeter.

Flowmeters: Eight turbine flowmeters shall be installed in the Laboratory Test Model to monitor the various branches of the air circulation system. Two capable of measuring rates of 1,400 pounds per hour shall be installed at the outlet of the Waste Unit. One, measuring rates of 2,800 pounds per hour, shall be installed after the main circulation fans. Smaller units, measuring 10 pounds per hour shall be installed at the inlets to the lithium hydroxide bed, the condenser and the heat exchanger. Two small units, measuring 0.5 pounds per hour shall be installed at the feeder vacuum cleaners.

Figure 20 illustrates the interconnection of the flowmeters. Each flow meter feeds an amplifier. One of the eight flow meters may be chosen for monitoring on the counter. The counter output is fed to a preset comparator that activates an out of limits alarm, as required.

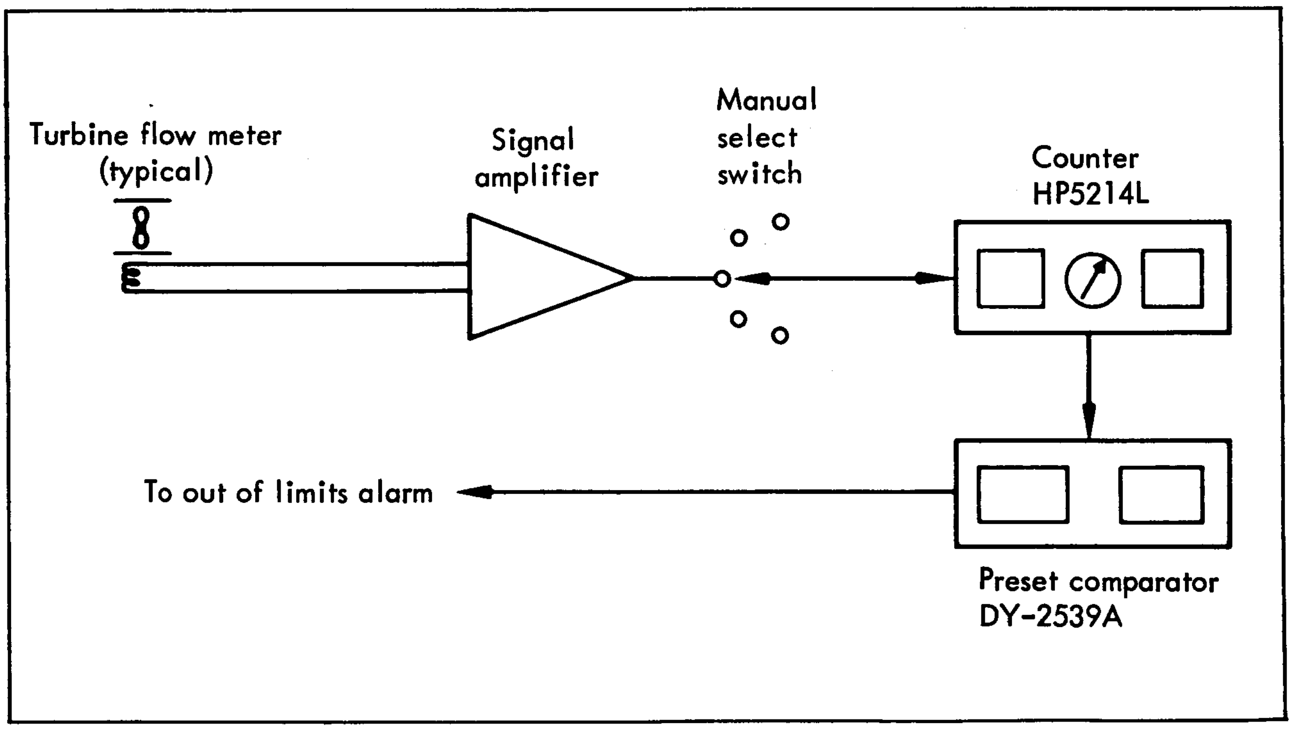


Figure 20.—Engineering instruments

Mass spectrometer: A Perkin/Elmer Mass Spectrometer (GFE) shall be utilized to determine the partial pressure of oxygen, nitrogen, carbon dioxide and the water content of the air entering the life cell. A similar spectrometer shall be included to measure the much smaller quantities of hydrogen sulphide, ammonia or other trace contaminants. A Perkin/Elmer vacuum pump will provide the necessary vacuum for the mass spectrometer.

Pressure transducers: Pressure transducers shall be provided to measure the difference in pressure across the main fans and across the contaminant fans. This information determines when to switch to a replacement fan.

A pressure transducer, shall measure the life cell total pressure that should be 17.0 ± 0.2 psia.

A differential pressure transducer shall be installed in the heat exchanger inlet to outlet.

An ion gage, shall be furnished to determine the degree of vacuum in the Perkin Elmer Mass Spectrograph.

Event sensors shall be switches, relay contacts and voltages picked off resistors in series with motors and lights. These events are recorded along with a time marker.

Support instrumentation. - The support instrumentation shall consist of a digital voltmeter, a counter and a digital comparator mounted in the control console. Auxilliary test equipment shall consist of a Tektronics Oscilloscope, Type 530, and a Triplett volt-ohm-meter.

The digital voltmeter, Hewlett-Packard 3430A, shall be utilized to read dc voltages and the outputs of the load cell readout device. The digital comparator, Hewlett-Packard HP2539A is preset to upper and lower limits and compares these to an incoming signal, such as a flowmeter output, and signals an out of limits condition. The digital counter, Hewlett-Packard HP 5214L, shall be utilized to measure time intervals and flowmeter outputs.

Recorders: Several types of recorders shall be provided as specified below:

The eight outputs from the two gas analyzers shall be conditioned and recorded on an eight channel strip chart recorder, Sanborn 7700. Recording shall be continuous at slow chart speeds.

A 30-channel event recorder, Brush RE 330310 or a Sanborn 360, shall be utilized. Contact closures, dc and ac voltages are conditioned and recorded continuously at a slow chart speed. A time marker is also recorded.

A 24 point recorder, Honeywell Electronic 15, shall be utilized to record various thermocouple outputs. The recorder shall be set to print out one point every 24 seconds and shall scan all points every 30 minutes.

A Sony CVC-100 vidicon camera shall be mounted external to each life cell and shall view the life cell through a view port. A Sony PVJ-3040 video monitor may be manually switched to monitor the activities of either animal and, as required, the camera output may be recorded for future playback on the monitor.

Calibrated microphones in each Life Cell shall be manually slected for presentation on loudspeaker, an oscilloscope or a recorder. An audio amplifier and volume control shall be included. The microphone output shall be measured by a broadband rms sound level meter to determine the noise level within the life cell.

Both the video and audio information shall be recorded on a Sony EV-200 Video Recorder.

Mass/volume measurement device: The Mass/Volume Measurement Device shall be supported on a load cell and the Mass/Volume Measurement Device shall be constrained to vertical motion by five flexures attached to the device to eliminate rotation and sway. The Mass/Volume Measurement Device shall provide mass measurements four times a day. A door shall separate the device and the life cell and it shall remain closed except for measurement. When the primate enters the device, the door shall close, a reading shall be taken, and then the door shall be opened, releasing the primate, and closed upon its departure. The Mass/Volume Measurement Device dimensions shall be 14 by 16 by 14 inches.

Instrumentation description and performance. - A block diagram of the basic instrumentation approach is given in figure 21.

Television: The television monitoring approach is given in figure 22. Standard commercial equipment will be modified to provide Apollo quality television pictures. Primate voice will also be monitored as shown in figure 23. Locations and details of the television view-port design are given in figure 24.

Activity counter: The activity counter will consist of monitoring the biotelemetry receiver AGC output, shown in figure 25, on a strip-chart recorder.

Biotelemetry receiver: The biotelemetry receiving approach is shown in figure 25.

Sensors: A detailed list of data points to be sensed is given in table 16. A transducer will be provided to sense each of these parameters. The approaches for monitoring temperatures, gas flow, gas constituents, and events are given in figures 21, 26, 27 and 28 respectively.

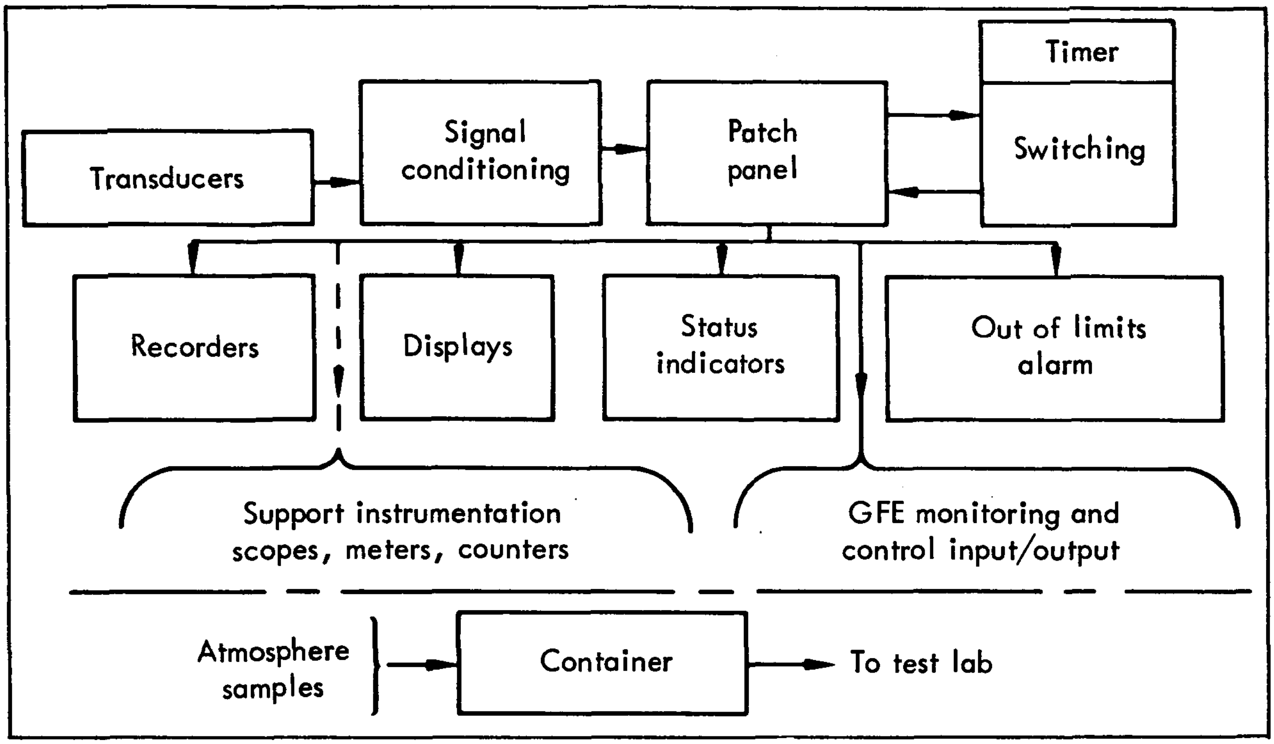


Figure 21.—Basic approach to instrumentation

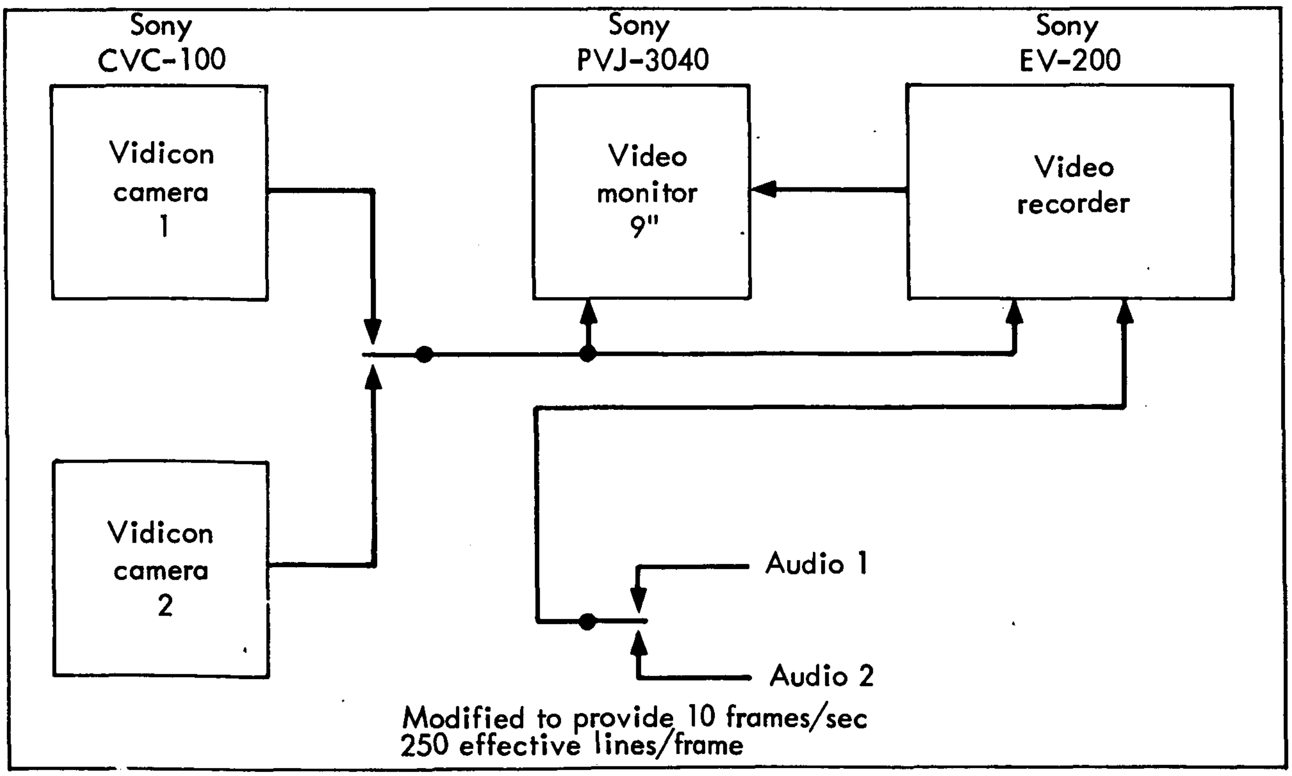


Figure 22.— Television monitors

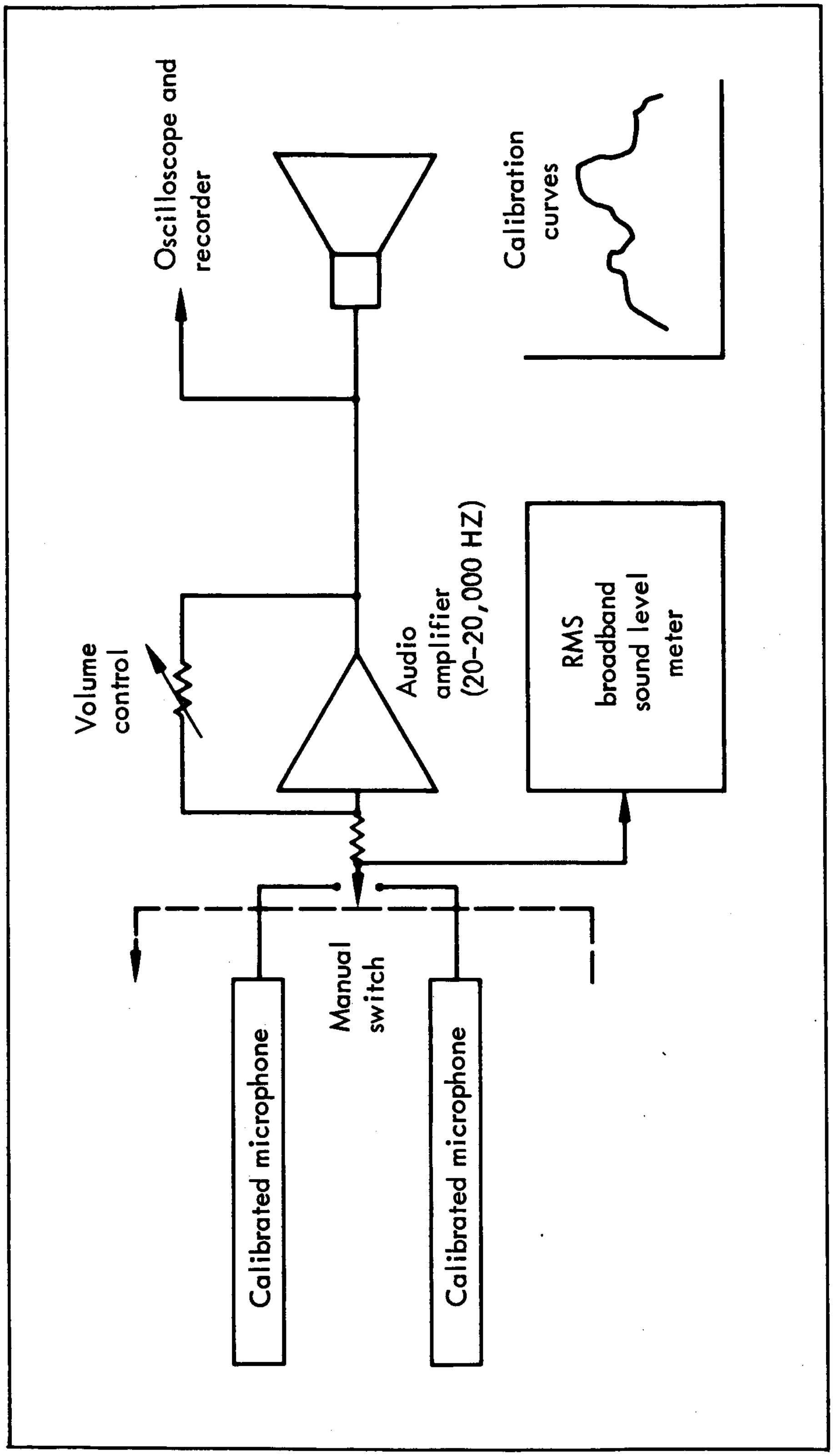


Figure 23. –Audio monitor

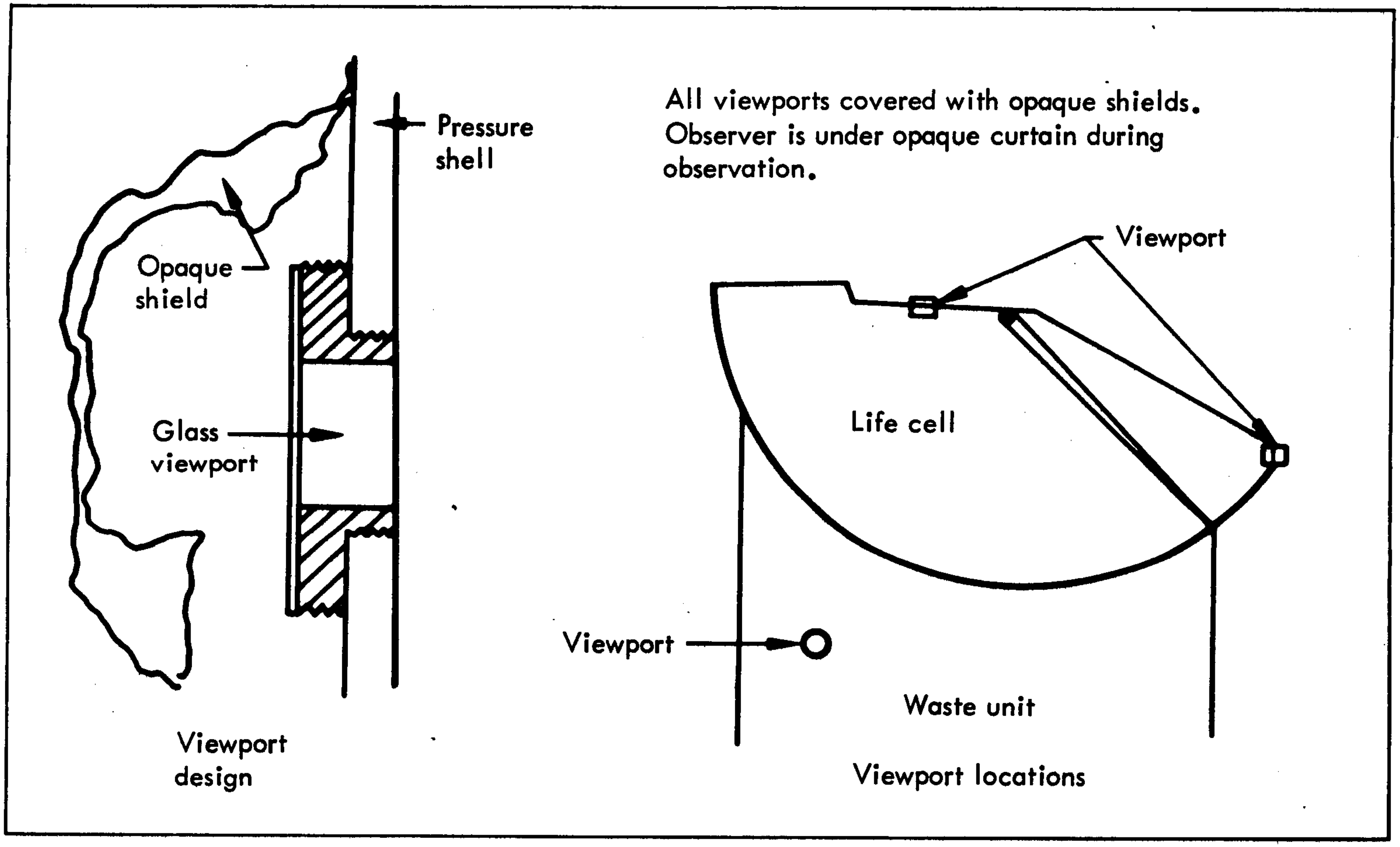


Figure 24. - Viewport design and locations

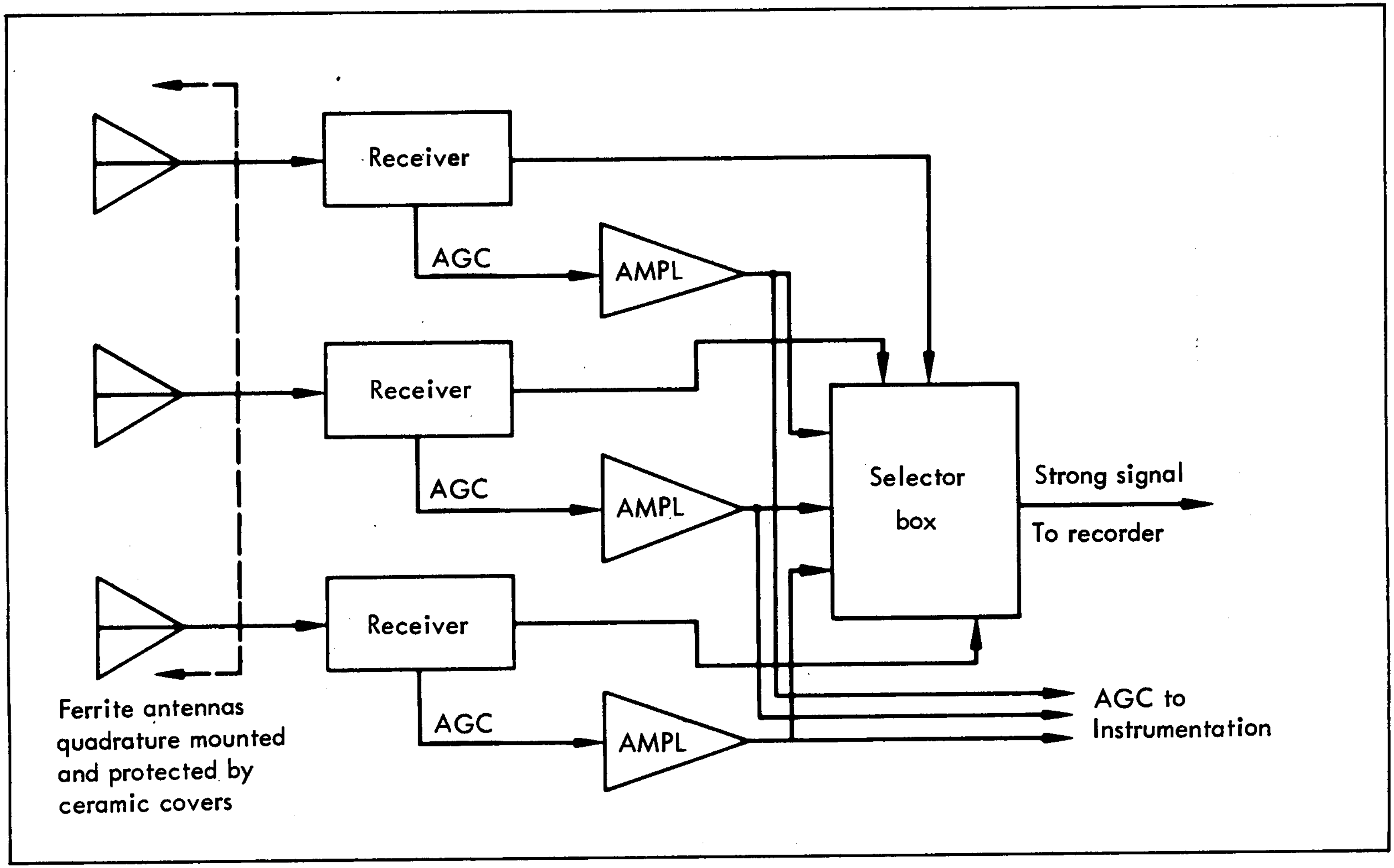


Figure 25.–Biotelemetry and activity monitoring

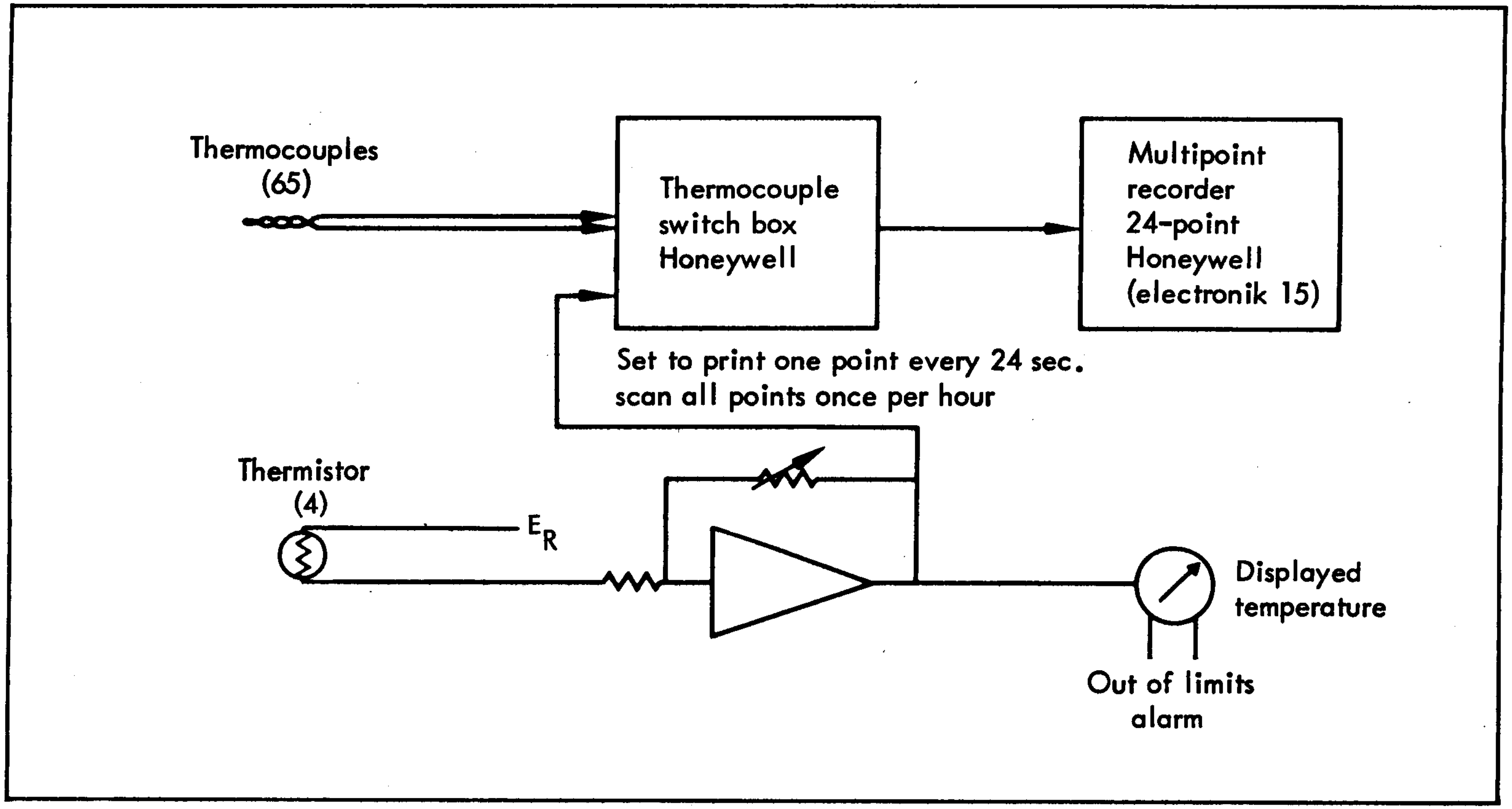


Figure 26.-Temperature monitoring, recording and engineering instruments

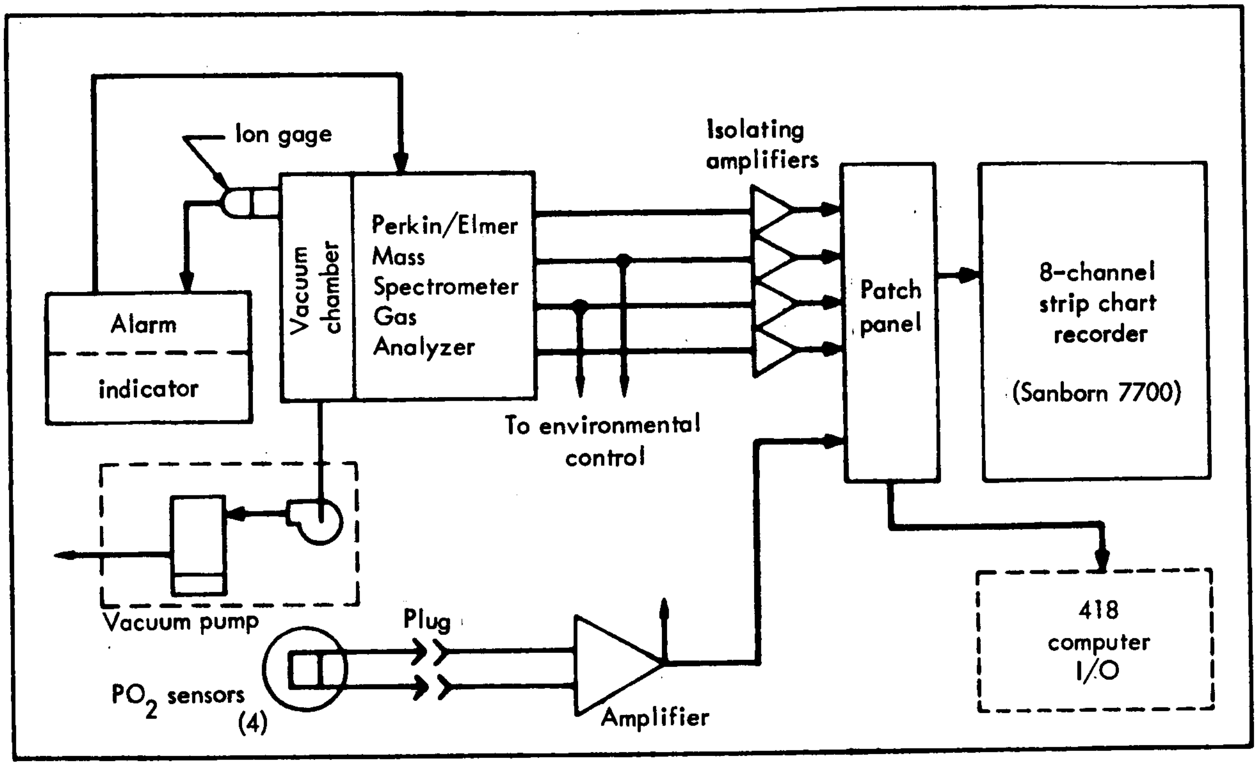


Figure 27.– Gas analyzers engineering instruments

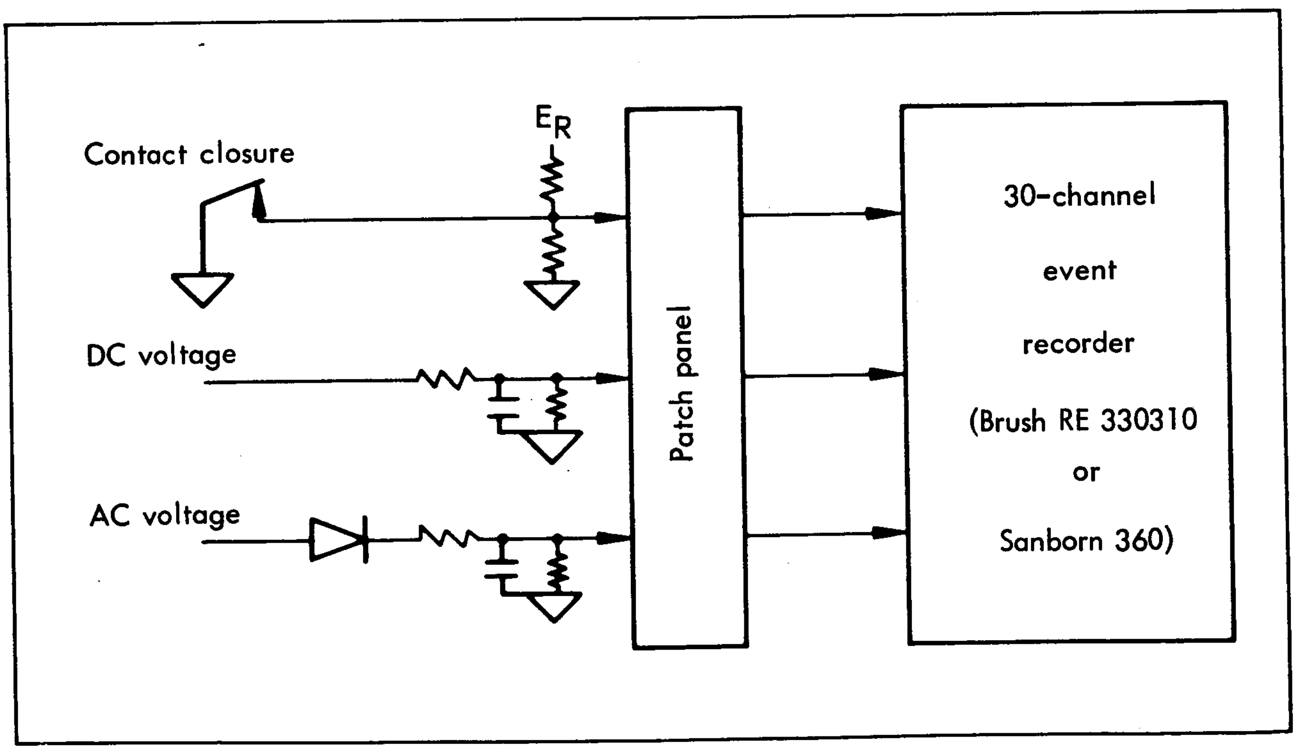


Figure 28.– Event recording engineering instruments

Support instruments: The support instruments including oscilloscopes, volt-ohm-meters, counters, shall be provided as a part of the Laboratory Test Model. This equipment will be used for trouble shooting and to monitor the performance of equipments not listed in the Measurements Requirements List.

The approach to monitoring primate mass is illustrated in figure 29.

Instrumentation preliminary equipment list. - A preliminary list of instrumentation equipment is given in table 17.

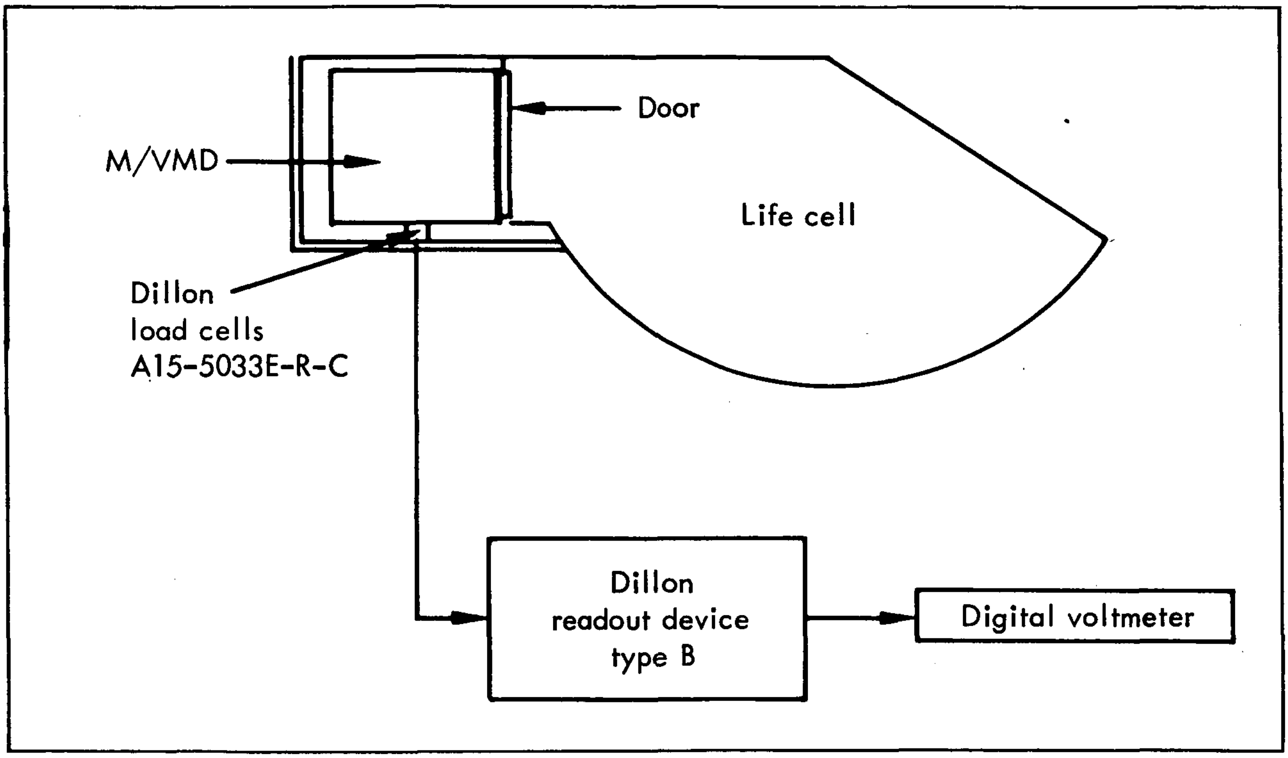


Figure 29.—Mass/volume measurement device

Command and Control Subsystem

The Command and Control Subsystem function encompasses controls, sequencing, displays, power control and distribution, and cabling. The primary function of this subsystem is to electrically integrate the diverse elements required to exercise control over the Laboratory Test Model and to provide the displays necessary to implement the control function.

Command and control subsystem requirements and constraints. - The Command and Control Subsystem is required to implement the following requirements:

(1) Provide a central control console for housing electronic equipment and displays and to serve as the operational control center.

TABLE 17. - INSTRUMENTATION PRELIMINARY EQUIPMENT LIST

Item No.	Description	Suggested Manufacturer	Part No.	Quantity per LTM
1	Television camera	Sony	CVC-100 (Modified)	2
2	Microphone			2
3	Biotelemetry antennas	Northrop		6
4	Biotelemetry receivers	Northrop		6
5	Biotelemetry amplifiers	Northrop		6
6	Biotelemetry selector box	Northrop		2
7	Transducers	Refer to table 16		124
8	Digital voltmeter	Hewlett Packard	HP 3430A	1
9	Digital counter	Hewlett Packard	HP 5214L	1
10	Digital comparator	Hewlett Packard	HP 2539A	1
11	Oscilloscope	Tektronics		1
12	Volt-ohm meter	Triplett		1
13	Strip chart recorder	Sanborn	7700	1
14	Event recorder	Brush	RE 330310	1
15	Recorder	Honeywell	EL 15	1
16	Mass/volume measurement	Northrop		1
17	Activity moniter	Northrop		2

(2) Provide for automatic sequencing and timing of the test model subsystems; this is to include: cycling of the life cell lighting and sequencing to periodically record data; interfacing with the laboratory supplied computer.

(3) Provide manual controls to override the automatic controls and sequencing as well as to directly control equipment.

(4) Provide displays of various monitored functions to the operator. These shall include wet and dry bulb temperatures inside the life cells, air flow rate out of life cells, primate temperatures, oxygen partial pressure, and power parameter.

(5) Provide necessary power, power controls, and circuit protection for 120/208 v, 60 Hz and 28 vdc power.

(6) Provide all interconnecting wiring both externally and internally to the Laboratory Test Model and to minimize EMI and electrical interactions.

<u>Command and control subsystem description and performance</u>. - The mechanization of the Command and Control Subsystem is represented by figure 30. Standard commercial racks are used. The display equipment is mounted in the racks which also contain the patchboard, manual control and power control equipment and recorders. The control console also serves as the location for all audio and visual alarms. Ventilation of the rack equipment is provided by an integral blower for air circulation.

Program sequencer: The sequencing and switching functions for other than the behavioral panel are performed by this unit. It originates time sequenced signals by means of electric timers for periodic cycling operations. Combinations of relays and solid state switching are used to accept command signals directly from the control console or from the laboratory. Signals in turn are provided for control of the model equipments. Signal levels from 5 to 28 vdc will be accepted with output signals in the same range. Power switching components and circuitry are segregated and isolated on the chassis to minimize electrical interaction with the signal circuits. The chassis design provides for convection cooling and installation in a standard commercial rack.

Manual controls: The Manual Control Unit consists of all the manual electrical controls contained on the control console mounted on a panel which in turn is rack mounted in the console. It contains the switches and appropriate indicators for controlling the Laboratory Test Model equipment directly or remotely. Override controls for automatic or sequenced functions are also contained in the Manual Control Unit. In addition to the controls found in the console, direct manual overrides of the mass measurement device, recovery capsule doors, and life cell moving wall are provided.

Display panel: The display panel which is also located in the control console rack contains all the visual and audible indicators of monitoring, measuring and observing for the testing with the exception of some recorder displays. The displays consist of audio and visual types.

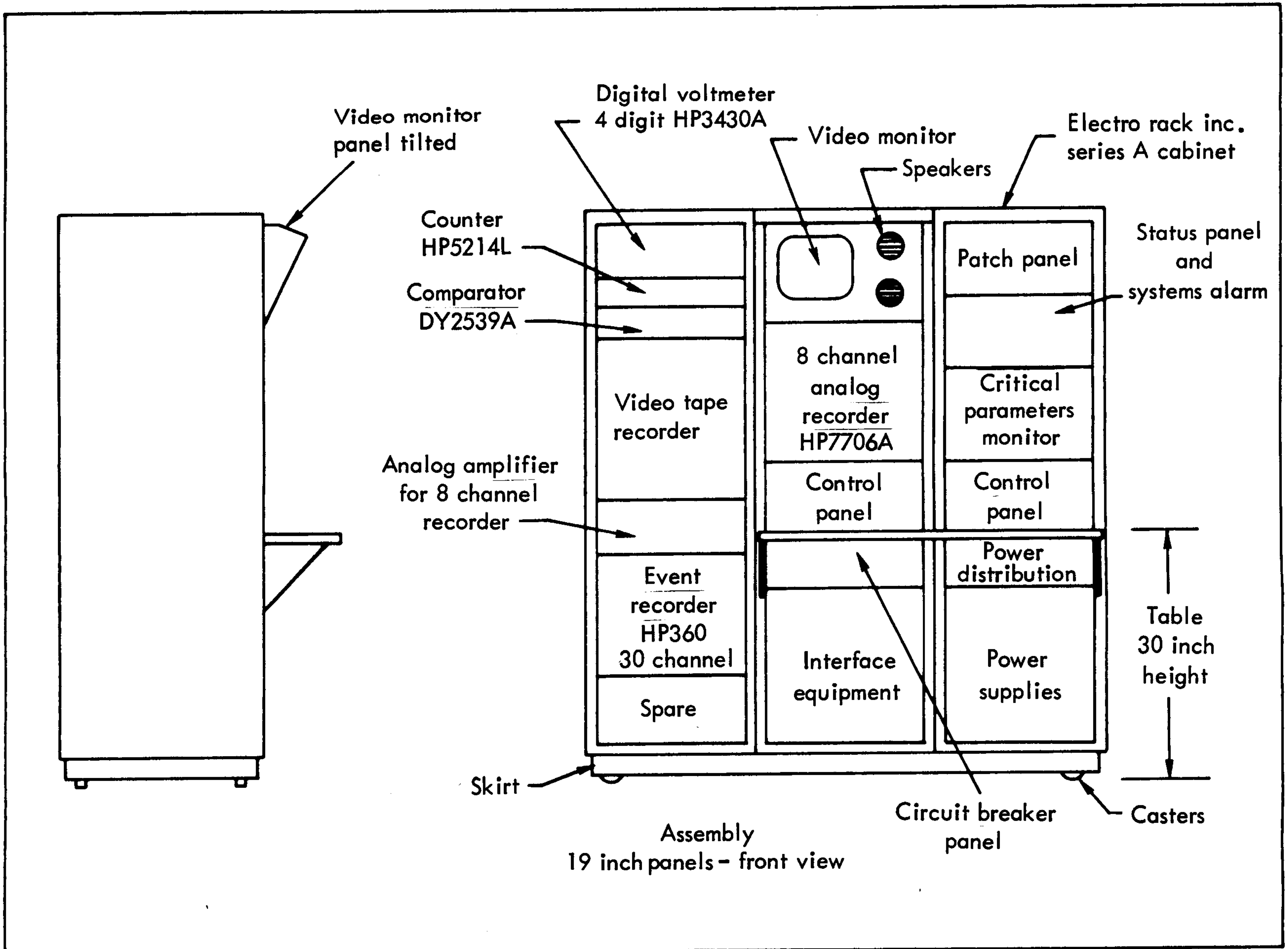


Figure 30.– Laboratory test model control console

The audio indicators are used to detect unsafe conditions either in the laboratory equipment or in the pressure vessel of the Laboratory Test Model. The critical parameters are gas flow, life cell temperature, and pressure. The indicator will be of the buzzer type with noise level external adjustment capability. For untended periods, a wall-mounted bell will be provided which will operate from the same circuits. The speakers associated with the audio monitoring and television audio will also be located in the display panel. Visual indicators on the display panel will consist of lights, meters, oscilloscopes, and television. Meters of the D'Arsonval type will be used to monitor voltages and currents of the individual circuits with circuit selector switches to permit multiple usage.

The ranges of the power monitoring meters will be 0 - 50 vdc, 0 - 50 amperes dc and 0 - 250 v, 60 Hz, 0 - 20 amperes 60 Hz commercial type, 5% accuracy panel mounting meters. Meters will also be used as position indicators for elements such as the mass measurement device and recovery capsule doors and the life cell moving wall. These meters will be of the 0 - 5 vdc relay type which will provide switch closures at the end of travel for operation of indicator lights. A digital voltmeter will also be used for precise measurements of some of the instrumentation subsystem voltages and for calibration purposes; counters will be used in conjunction with the flow meters to indicate fluid flows. Lights will be used to indicate status and to provide visual alarms. In the latter case, the lights will be driven by a switching circuit which will simultaneously cause the indicator lights to blink and the audio alarms to sound. Oscilloscope displays will be available with the appropriate selector circuits and switches to provide a visual indication of wave forms and voltage levels of any of the parameters being monitored. The oscilloscope will be a standard commercial type, panel mounted unit.

The video monitor unit which will form part of the closed circuit TV for each life cell will also be on the display panel and will display for one life cell at a time as selected.

Power control and distribution: A power control and distribution unit which consists of two panels is used in conjunction with the displays as a panel mounted center for control and circuit protection for all electric power used by the Laboratory Test Model. Manual switching of 28 vdc and 120/208 v. 60 Hz power is accomplished by this unit. Where levels of power are too high to be switched directly through the switch, the latter acts as a control for a power switching relay located remotely. Individual circuit controls for all major Laboratory Test Model circuits are provided. Manually resettable circuit breakers for each of these circuits are also provided; busses feeding from these main circuits are protected by fused lines going directly to the individual items of equipment. The coordination of breakers and fuses is such as to preclude a complete shutdown due to failures in individual circuitry. The circuit breakers are selected to provide distribution system protection while the fusing located closer to the equipment itself will provide equipment protection. The distribution of power will be by means of a two wire single point ground system for the 28 vdc which is the basic power for the spacecraft equipment. This will serve to provide a proper match to this latter equipment as it is used in the Laboratory Test Model and in addition, will aid in minimizing EMI and electrical interactions which are fostered by multiple ground loops.

Cabling: The cabling which will serve to electrically interconnect the various elements of the Laboratory Test Model supporting and monitoring equipments will consist essentially of two types of wire. MIL-W-16878D and commercial grade wire.

The MIL-W-16878D wire will be used for all wiring internal to the Laboratory Test Model while the commercial grade wiring will be used for external circuitry. This approach is desirable because it permits exposure of the wiring intended for the spacecraft to actual atmospheric and contaminant conditions as will probably be found in the spacecraft during the mission. Thus, an advanced evaluation of the wiring insulation under such conditions can be made. Since the cost of this wiring is somewhat greater than the commercial type, for purposes of economy, it is desireable to use the latter wherever no significant benefit accrues from using the MIL-W-16878D wire.

Wiring will be segregated and routed in separate power and signal cables in order to minimize EMI and electrical interactions. A commercial type patch panel will be used to provide flexibility in making circuit connections and changes as desired. Shielded wire will be used in sensitive signal circuits, twisted shielded pairs will serve to attenuate outputs of noise generating circuits.

Behavioral control interface unit: This equipment permits the use of the 418 Computer and Program Controller, both GFE. It acts as an interface between these two units, the behavioral panel in the Laboratory Test Model and the patch panel in the control console. The behavioral control interface unit will consist essentially of line drivers and terminators as shown in figure 31 with associated storage and logic devices to permit acceptance and conditioning of signals from the program controller, 418 Computer, and behavioral panel. Approximately 40 line drivers and terminators will be required to permit flexibility in the control and monitoring of the behavioral panel operation.

<u>Command and control subsystem preliminary equipment list</u>. - Table 18 represents a preliminary estimate of equipment requirements for the Command and Control Subsystem. Only major items are noted in most cases, and where information is lacking, no entry has been made.

OPERATIONAL TESTING

The test program will be conducted at the Naval Aerospace Medical Institute, NAMI, at Pensacola, Florida as a contractor supported effort for a twelve-month period. It will be conducted under the cognizance of the NASA/LRC and/or the NAMI Principal Investigator, who will be supported by the contractor organization under the cognizance of the contractor test director. The functional relationship is identified in figure 32.

The test director will assure the orderly progress of activity in accordance with the test procedure; provide for necessary maintenance or repair of the model; implement modifications as required by evaluation of equipment perform-

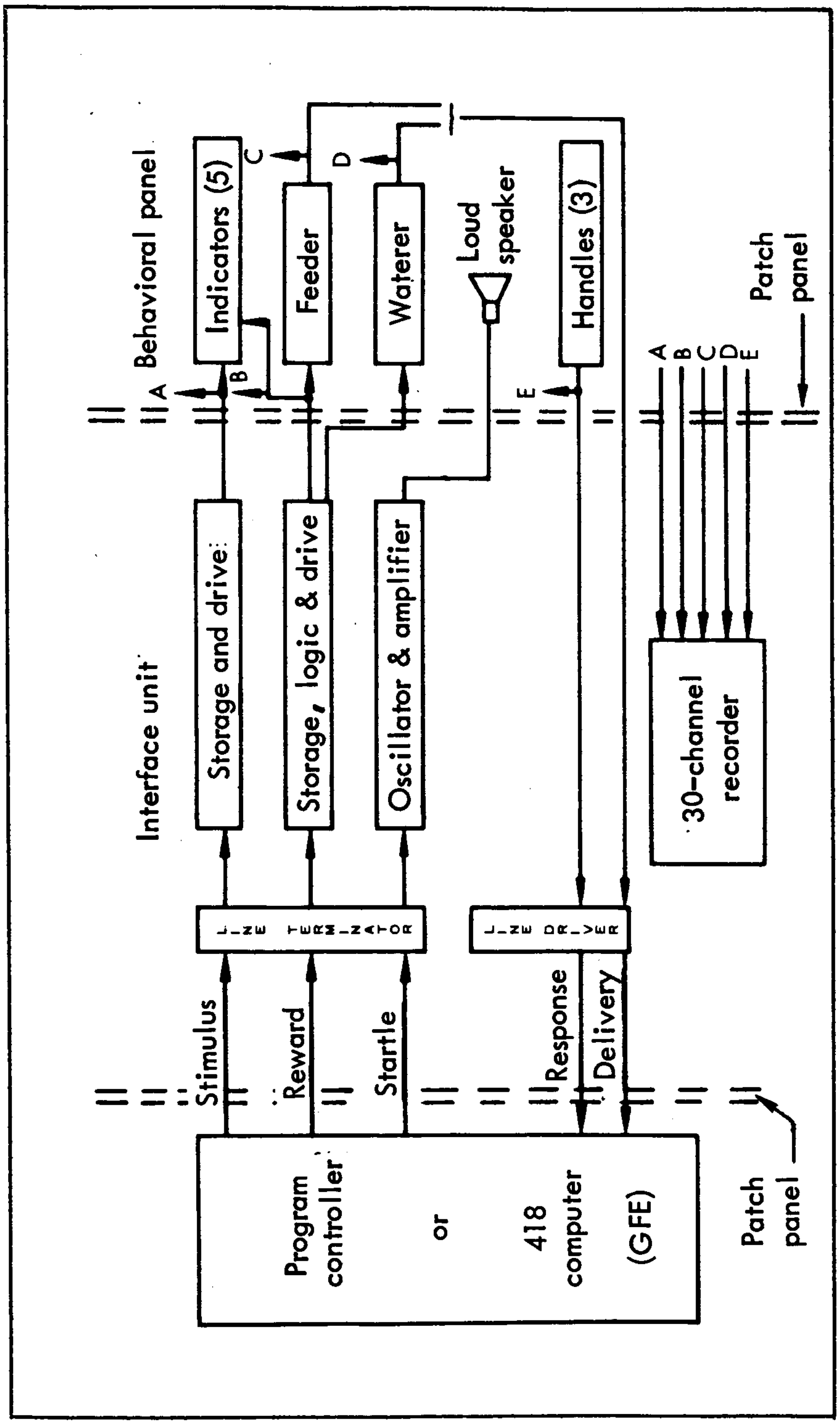


Figure 31.—Behavioral control block diagram

ance or to support deviations in the primate interfaces requirements as may be established by the Principal Investigator; and assure the effective operation and calibration of test instrumentation. The test director will arrange for the contractor non-resident cognizant engineers to trouble shoot and advise on the subsystems should any major performance discrepancy arise; resident personnel will resolve minor discrepancies to assure continuity of the program.

Test Support Equipment

The test equipment required to support the Laboratory Model Test Program consists of the data acquisition system for monitoring, recording, and analyzing the biological, behavioral, environmental, and engineering information. Both the biological and the behavioral data outputs will be provided as 0 - 5 v analog signals to the GFE data acquisition system presently in use at NAMI. The data will then be scanned, digitized, and processed by a Univac 418 Computer for storage and analysis. The environmental and engineering data will be processed by contractor furnished equipment to yield primarily strip chart

TABLE 18. - COMMAND AND CONTROL SUBSYSTEM PRELIMINARY EQUIPMENT LIST

Item No.	Description	Suggested Manufacturer	Part No.	Qty
1	Equipment rack	Electro Rack, Inc.		3
2	Timers - 24 hr, synchronous, motor driven	Haydon Corp.		4
3	Bio-telemetry selection box	Northrop		2
4	Loud speakers - 8 inch	University		1
5	Audio selector switch - 3 position	Centralab	1461	1
6	Audio volume control	Allen-Bradley		2
7	Gas flow meter position selector switch, eight position	Allen-Bradley		1
8	Patch panel	Vector		1
9	Voltmeter - 0-50 VDC 5% acc.	General Electric		1
10	Ammeter - 0-50 amps, DC 5% acc. (with shunt)	General Electric		1

TABLE 18. - (Concluded)

Item No.	Description	Suggested manufacturer	Part No.	Qty
11	Voltmeter - 0-250 V 60 cy 5% acc.	General Electric		1
12	Ammeter - 0-20 amps, 60 cy 5% acc.	General Electric		1
13	Selector switches, rotary, 4 position - amp contacts	Cutler Hammer		4
14	Meter - relay - 0-5 VDC - 1 amp contacts			2
15	Broad band RMS sound level meter			1
16	Power switches - 28 VDC			
	5 amps			4
	10 amps			4
17	Power switches - 120 v, 60 cy			
	5 amps			2
	10 amps			2
18	Battery - 28 VDC, 36 A-H	Mallory		1
19	Behavioral control inter-face unit	Northrop		1
20	Circuit Breakers	Cutler-Hammer		
	1 amp - 28 VDC			4
	5 amp - 28 VDC			4
	10 amp - 28 VDC			3
	50 amp - 28 VDC			1
	5 amp - 115 V - 60 cy			2
	10 amp - 115 V - 60 cy			2
	20 amp - 115 V - 60 cy			1
21	Video Monitor	Sony	PVJ-3040	1
22	Video recorder with audio track	Sony	EV-200	1
23	Audio amplifier	EICO	ST-40K	1
24	Power Distribution Module	Square D		1

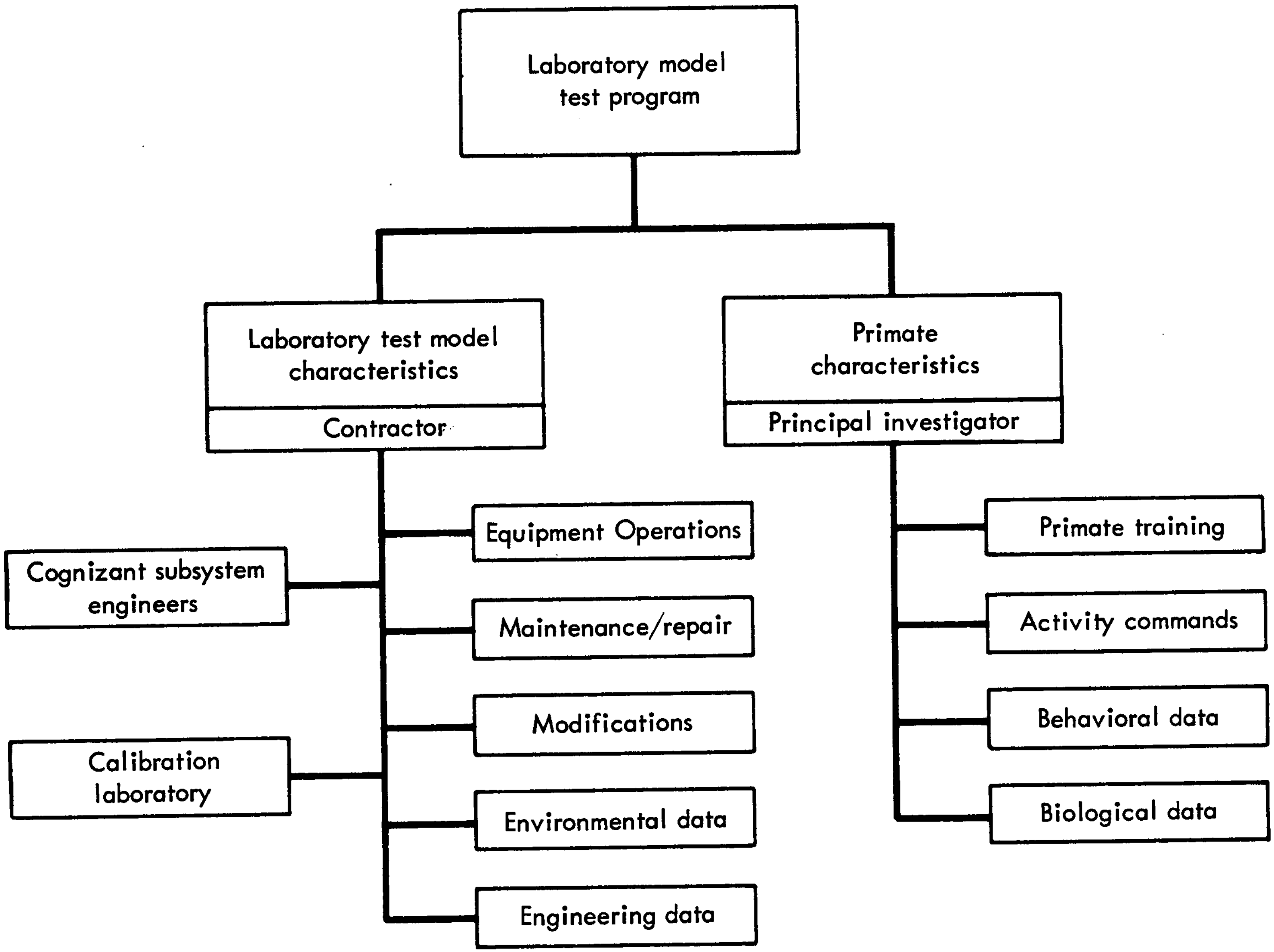


Figure 32.—Laboratory test model test program functional relationship

points by the use of portable laboratory meters. Provision will exist for continuous recording of selected components as required for more detailed analysis, evaluation, or trouble shooting.

Test Procedures

The Laboratory Model Test Procedure will be prepared by the contractor prior to delivery of the test model. The test procedure will identify the test model to the level at which measurements will be made. It will also specify the measurements and method of frequency for making the measurements. Measurement requirements tables will be included to organize and simplify the logging of data. The test procedure will be prepared for the NASA/LRC review and approval three weeks prior to delivery of the Laboratory Model. Revisions to the test procedure during the actual test operations may become necessary due to the experimental nature of some aspects of the program; any procedural revisions will require the approval of the NASA/LRC. A preliminary overall test procedure from completion of manufacture to completion of testing is in the following subsections.

Post manufacturing test of life cells. - An animal will be installed in each of the life cells to check out mechanical operation of the cage flow, recovery capsules, etc. This test will require approximately one day.

Post assembly test of life cells. - After the life cells and Environmental Control Systems are installed in the pressure shell, a short functional test will be conducted to assure overall compatibility of subsystem components and the animals.

Functional check of laboratory facility. - After the Laboratory Test Model is shipped to the laboratory facility, a second functional check will be conducted to check for shipping damage, compatibility of Laboratory Test Model with facility, etc. Animal need not be installed.

One year test. - Both animals are installed and the one-year test is begun. Monitoring during the first two weeks will be intensive. After it is determined that all subsystems and the animals are functioning properly, a system dynamic range study will be conducted. This will involve a check of the Environmental Control System's ability to control the animal environment when heating and cooling input from the Thermal Control Subsystem is varied. The maximum allowable ranges will be determined.

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format information. The capability will exist, however, for selective data channels to be monitored and processed by the NAMI Computer facility. Strip chart recordings will be provided by multipoint recording potentiometers for temperature nd humidity, and a multi-channel oscillograph for pressure, current, voltage and ction measurements. A digital counter will be provided for periodically monitoring atmosphere flow-meter outputs, and an indicating potentiometer will permit periodic monitoring of the oxygen sensor output. Additional indicating equipment which will be required includes pressure gages, flow indicators, and portable ammeters and voltmeters.

Test Description

Life support. - Measurements will be made of system air velocities in the various elements of the system ducting network to verify proper flow rate and distribution of the gas mixture. Gas flow will also be monitored in the lines downstream of the gas supply regulators to verify make-up gas usage. The gas storage bottles will be mounted on beam balance scales to monitor long-term mass transfer to the life cell. In addition, the gas storage bottles will be monitored for pressure and temperature as a cross-check on gas usage. Air temperature and humidity will be continuously monitored in the life cell and ducting to permit engineering evaluation of the operating characteristics of the life support air conditioning system. Air pressure will be monitored in the life cell for absolute pressure determination and across each fan in terms of pressure differential for evaluation of fan performance. The waste storage unit will incorporate a bank of thermocouples for monitoring the temperature profile in the waste bed. The ducting downstream of the waste unit will be monitored for gas flow rate and humidity to determine if clogging of the waste unit occurs and to determine wet and dry cycles of the waste matter. Air samples will be periodically extracted from the system and transported to a chemical laboratory for analysis of the gas constituents. Lithium hydroxide bed core samples will be extracted periodically and submitted to laboratory chemical analysis to evaluate the composition and condition of the hydroxide bed. Drinking water use rate and food pellet consumption will be monitored to determine the primate consumption rate; this data will be provided in dual outputs to permit recording concurrently by the facility computer network and laboratory instrument recorders.

Instrumentation. - Television monitoring of the primate's activity and cage characteristics within the field of view, will be recorded by video tape. Primate audio outputs will be concurrently recorded by video tape during its cycle of operation and will be continuously monitored by a conventional speaker within the laboratory. Biotelemetry data transmission from the primate implants will be received by on-board antenna, processed by commercial type signal conditioners, and transmitted by hard line to GFE facility equipment. Provision will exist for parallel recording by contractor furnished analog equipment. Activity monitor outputs will be dually monitored by the facility computer network and the laboratory event recorder.

Electrical power. - The total power consumption of the laboratory model system will be monitored and recorded continuously. Individual power demand rates of the various system components will be periodically sampled at jack